Vol. 54 No. 2 October 1960

Quarterly

of the

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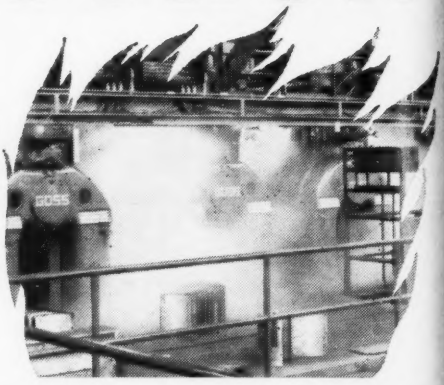

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Quarterly

The Standard Technical Journal of Fire Protection for More Than Fifty Years

The NFPA is a nonprofit technical and educational organization devoted to the reduction of loss of life and property by fire with a total membership of nearly 18,000. The QUARTERLY is one of the publications regularly provided to members. Other membership publications include *Fire News*, *Advance Reports* to the Annual Meeting, a *Year Book*, and many leaflets, pamphlets, and posters issued throughout the year on fire prevention and control. Seven volumes of the National Fire Codes are available on an annual subscription basis, one volume free and others at reduced membership rates. For full details on available material ask for a free list of "Publications on Fire Prevention and Protection."

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International

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Quarterly

of the

NATIONAL FIRE PROTECTION ASSOCIATION

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With a nuclear weapon exploding at a low altitude, there will be some separation between the fireball and materials on the ground. This produces results different from a burst at ground level (see photo, page 105).

Fire Effects of Big Nuclear Bombs

By Frank McNea, Director

Fire Division, Office of Civil and Defense Mobilization

Executive Office of the President (U. S. A.)

In a nuclear war an extremely serious fire problem would develop in broad areas around the ground zero locations of the detonations. Unchecked, these fires would rage out of control and, in most areas, would consume all combustible material from the ground zero locations to natural or man-made firebreaks.

Nuclear weapons range in size from less than 1,000 tons of TNT equivalent up to the giant thermonuclear devices in the megaton* range. The delivery of these weapons could be accomplished by aircraft, guided missiles, ship, or clandestine means.

We do not know the size of the bomb the enemy might use or for what altitude an enemy might set the fuse.

Variation in the altitude of burst would alter the effects-distance relationship and the extent and limits of the fire defense problem. This paper illustrates the variation in the damage effects resulting from a megaton nuclear weapon exploded at three different levels: (1) The surface detonation of a 10-megaton weapon, (2) the air burst of this weapon at 3 to 4 miles above the earth's surface, and (3) a very high air burst of the same weapon at 20 miles above the earth's surface.

The surface burst of a 10-megaton weapon would create a large area of initial fire formation, great blast damage, and a serious radiological fallout problem. An identical weapon exploded at a height of 3 to 4 miles would create a larger fire area, increase blast damage area, but would not create a serious fallout problem. The same size weapon detonated at 20 miles above the surface of the earth very likely would create an extremely large fire area, but no blast damage or nuclear radiation problem.

Ground Detonations

If a 10-megaton nuclear weapon was detonated at the surface of the earth, the explosion would create a crater in the ground about 2,500 feet in diameter and perhaps 240 feet deep. Around the crater would be a rupture zone, a region having a diameter about twice the crater diameter. No structure or its occupants would survive within this region. The fireball from the detonation would be over 2 miles wide with temperatures several million degrees Fahrenheit in the inner portion of the fireball. Out to almost 4 miles from ground zero there would be virtually complete devastation. All buildings would be destroyed and probably everyone would be killed in this area. Severe blast damage would be expected out to about 6 miles from the point of detonation with minor blast damage extending to beyond 10 miles from ground zero.

Blast Effects from Ground Detonations

In general, the blast effects would collapse buildings; displace unanchored objects; rupture gas, oil, and water pipes; cause electrical short-circuits; upset stoves, furnaces, and open flame operations; and shatter windows and

Based on a paper prepared by the author for presentation at the National Fire Defense Seminar sponsored by the Office of Civil and Defense Mobilization.

*A megaton is a million tons.

doors. Fires caused by blast effects are called secondary fires. Blast effects also would damage the fire protection of buildings, cause structural damage which would make buildings more vulnerable to rapid burning, and cover the firebreak areas with combustible debris. An overpressure of one-half pound per square inch would break most windows and cause secondary fires beyond 25 miles.

The detonation of a 10-megaton weapon at ground level produces the following overpressures at the indicated distances from the point of impact:

Overpressure Pounds per Square Inch	Distance Miles
200	1.0
100	1.4
50	1.9
20	2.8
10	4.1
5	6.1
2.5	9.7

Fire Effects from Ground Detonations

Numerous fires would quickly develop at various locations, out to about 12 miles from ground zero. The thermal energy received at this distance, with a 10-megaton surface burst, would be about 12 calories per square centimeter and would cause third degree burns to exposed persons, ignite unsound wood, rubbish, paper, upholstery, curtains, deciduous leaves, dry brush, and fine grass. In the area between 12 and 15 miles from ground zero, there would be many additional ignitions from the blast and thermal effects. At 15 miles, the thermal energy received would be approximately 8 calories per square centimeter, cause second degree burns to exposed persons, and ignite relatively light flammable debris lying out in the open.

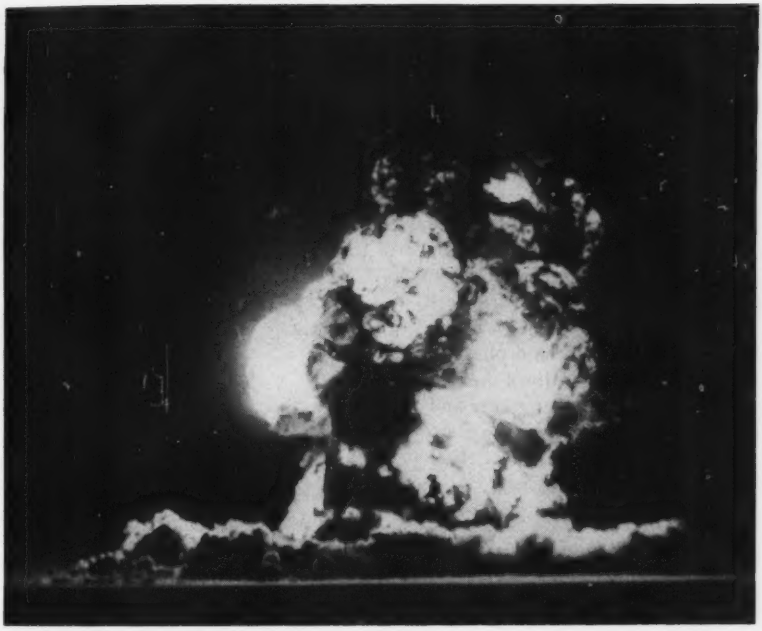
Generally, the formation of significant fires, capable of spreading, requires appreciable quantities of combustible material located in close proximity to the ignited material. This situation does not always exist.

The spread of fires in a city depends upon a variety of conditions, for example: weather, topography and closeness, size and combustibility of buildings and their contents. The most important factor to be considered in determining the probability of fire spread in a community is the distance between buildings. For example, the lower the building density of an area the less is the probability of fires spreading from one structure to another. Further, the larger the space between buildings the greater is the chance that the spread of fire can be controlled.

Fire Effects in Forests

Another aspect of fire spread is the development of mass forest fires. The thermal energy required to ignite forest fuels is largely dependent on the moisture content of the fuels at the time of the explosion. Green leaves and the trunks of trees act as shields against thermal radiation so the number of points at which ignition would occur in a forest may be less than would appear at first sight. Dried leaves, grass, unsound wood, and some other fuels would ignite at a distance of about 10 miles from the explosion if exposed to thermal energy of 12 to 18 calories per square centimeter. These ignitions could then set fire to other fuels which were not ignited by the thermal effects of the explosion.

Some factors which influence the growth of fires are moisture content of trees, topography, and meteorological conditions. Low atmospheric humidity, strong winds, and steep terrain favor the development of forest fires. In general, a deciduous forest, particularly when in leaf, would burn less rapidly and with less intensity than a forest of coniferous trees.



Ground burst showing how ground material is disturbed to produce radioactive particles of dust and debris from which "fallout" effects result.

Fallout with Ground Detonations

Since this 10-megaton weapon is assumed to be detonated at the surface of the earth, there also would be a serious radiological fallout problem for a few miles upwind and crosswind of ground zero, and perhaps 200 miles downwind of ground zero. Since heavy exposure to fallout radiation can cause serious injury and even death to people, the exposure of fire-fighting personnel in an area of radioactive fallout should be limited and controlled.

The unit of radiation exposure is called roentgen (r). The most recent information indicates that emergency personnel, such as police, firemen, and other civil defense workers, required to carry out vital priority tasks, could be exposed to a total dose of as much as 200 r over a period of a month or less. An exposure of 200 r over a short time would cause some nausea, but it probably would not interfere with a person's ability to carry on with his job. Therefore, in fighting these widespread fires during the early periods after attack, the radiation exposures of firemen should be limited to no more than 200 r. We shall assume then that fire-fighting personnel will be able to work approximately 20 hours in the fallout area, where the radiation level is not more than 10 r/hr, before the rotation of personnel would be required.

Assuming a 10-mile-per-hour wind and the detonation of a 10-megaton surface weapon, the 10 r/hr dose-rate condition would extend for about 6 miles upwind of ground zero, about 10 miles crosswind, and for several hundred miles downwind. Any prolonged emergency

operation, such as fire fighting, could not be carried out within this area without serious radiation exposure to personnel. Under actual conditions, radiation dose rate contours do not follow smooth and continuous lines and must be determined by radiological monitoring. Small areas or pockets of greater or lesser fallout radiation would exist throughout the areas. This uneven distribution of radioactive particles would result from the strong inward draft at ground level which exceeds 275 miles per hour during the suction phase of the explosion. The updraft of heated air over the extensive burning area and the continuing strong inward draft at ground level would also affect the location of radioactive particles.

The 10 r/hr contour would be found closer to ground zero on each subsequent day because of radiological decay. For example, on the second day the 10 r/hr contour would extend only 3 miles upwind and, on the third day after the attack, perhaps only 2 miles upwind. On the crosswind side, the 10 r/hr condition, which initially extended out to about 10 miles from ground zero, would only extend out to about 4 miles on the second day and perhaps only out to 3 miles on the third day. However, in the immediate vicinity of the detonation and downwind of this area, the dose rates probably would exceed 10 r/hr for several days and possibly for two weeks or more.

Under these conditions and using the 10 r/hr dose rate as an exposure criterion, fire-fighting personnel could perform emergency operations during the first day, if necessary, to within 6 miles of ground zero on the upwind side. During the second day they probably could enter the area to within 4 miles of ground zero on the crosswind side. As the zone of complete devastation would extend outward for almost 4 miles from ground zero, there would be no fire defense activity within this zone. However, fire department personnel would be expected to assist in, and where assigned the responsibility, direct the rescue of persons from shelters, basements, and other sub-surface areas outside the crater area. Organized fire-fighting operations would originally be conducted outside of the area of heavy blast damage.

On the downwind sector from ground zero, fire fighting would be seriously hampered for a considerable time because of severe fallout. Very little emergency operations or recovery measures would be undertaken downwind of ground zero before 1 or 2 weeks after attack. However, in these areas, there would be areas of lesser radiation hazard where fire defense measures would be carried out earlier. Actual determination of entry time and period of stay for operational purposes would be based upon radiological monitoring and evaluation. In the event of a surface burst, the areas of most likely fire defense operations would be on the crosswind and upwind sectors. Under priority actions, such as firefighting to save vital installations, a criterion greater than 10 r/hr might be adopted. However, this decision would have to be made by the fire chief or mayor at the time and place of the occurrence based upon the dose rate and the operational time required in the fallout area. The biological penalty involved to firemen must be weighed against the importance of saving vital installations by extinguishing fires during the early period when they can be more easily controlled.

Air Burst, 3 to 4 Miles Up

The same 10-megaton weapon is assumed to be detonated 3 to 4 miles above the surface of the earth. Since the fireball does not touch the earth's surface, there likely would be no serious fallout

This is a day view of a low air burst taken during the 1957 Nevada tests. The radioactive cloud can be seen moving out. At the moment this picture was made, radiant heat was igniting brush on the hills in the background.

condition anywhere around the target even on the downwind sector. Further, there probably would be no cratering action such as with a surface burst. It could be assumed that the zone of complete devastation would extend to beyond 4 miles from ground zero with light structural damage extending out to about 14 miles.

Numerous fires would form throughout the area during the first few minutes after detonation to almost 20 miles from ground zero. With an air detonation, the thermal energy received at 20 miles from the point of explosion on a clear day would be about 12 calories per square centimeter. Out to about 24 miles from ground zero, the thermal energy received would be 8 calories per square centimeter and scattered fires would be expected. Out beyond this distance, some primary and secondary fires also would be expected.

As far as the radiation problem is concerned, fire-fighting operations could be undertaken as soon as possible at any feasible location beyond the zone of complete devastation. The potential zone of serious fires would extend out to 20 miles from ground zero. Therefore, the area of operation would be at selected locations well outside the severe blast damaged area.

Air Burst, 20 Miles Up

With the same 10-megaton weapon detonated at 20 miles altitude, there would be no close-in fallout problem and little blast damage. With nuclear detonations at these extreme altitudes, almost all of the weapon's energy would be expended in the form of heat, whereas, with a surface burst, only about one-third of the weapon's energy would be expended in the form of heat. Consequently, the area of numerous fire formations would be much greater for a high altitude burst. Very few nuclear tests of this very high altitude type have been carried out, therefore, it would be difficult to define precisely the extent of the fire problem. Tentative data indicate that serious fire would form after such a detonation as far as 25 miles out from the point on the ground immediately under the weapon. Beyond this, out beyond 30 miles, there would be scattered light fire formation.

Summary of Effects Related to Levels

Thus, with a surface nuclear detonation, the area of initial fire formation would be less, but fire-fighting operations may be hampered somewhat on the crosswind and upwind sides because of nuclear radiation and in the downwind area probably only limited fire defense measures would be accomplished during the first two weeks. With a low air burst, the initial fire problem and area of blast damage would be greater, but there would be no fallout problem to interfere with fire-fighting activities. Finally, with a very high altitude burst, the area of serious fires would be extremely large, but there would be no nuclear radiation problem and no blast damage.

In the foregoing description of the three types of bursts, reference to wind direction was confined to the upper level winds as they relate to the direction of radiological fallout.

The direction that fire travels is governed by the velocity and direction of surface wind and the combustible material in its path. The area and level of radiological fallout in the periphery of the attacked area depend on the yield of the weapon, height of burst, and on the velocity and direction of the integrated winds, from the earth's surface to the top of the cloud containing radioactive material. This upper level varies in relation to the yield of the weapon used and ranges from 40,000 to over 120,000 feet.

The wind at surface level and in the upper level is frequently in different directions and may vary as much as 180 degrees. Therefore, a sound evaluation of the postattack fire situation must include current information on the direction and velocity of the wind at both surface and upper level.

Atmospheric Conditions

The thermal effects given in each of the three examples are those received with exceptionally clear visibility at the time of the burst. The actual thermal effects range would be reduced by limited visibility at the time of the explosion in the same manner that fog or haze reduces the heat received from the sun.

In a vacuum, intensity of thermal radiation from a point source would decrease according to the inverse square law. (One-fourth the value at twice the distance, one-ninth the value at three times the distance, and so on.) However, thermal radiation is also reduced by air absorption and scattering.

Atoms and molecules present in the air absorb radiant energy. Because of absorption, the amount of thermal radiation decreases markedly within a short distance from the explosion. The decrease in energy of thermal radiation due to scattering by particles present in the air depends upon the atmospheric conditions, such as the concentration and size of the particles, and also on the wave length of the radiation. The state of the atmosphere, related to scattering, will be represented by what is known as the "visibility range." This is defined as the horizontal distance at which a large dark object can be seen against the horizon sky in daylight. A rough correlation between the visibility and the clarity of the atmosphere is as follows:

Atmospheric Condition	Visibility Miles
Exceptionally clear	More than 30
Very clear	12–30
Moderately clear	6–12
Light haze	2.5–6
Haze	1.2–2.5
Dense haze or fog	Less than 1.2

If an air burst occurred above a layer of dense cloud, smoke, or fog, an appreciable portion of the thermal radiation would be scattered upward from the top of the layer. In addition, most of the radiation which penetrates the layer would be scattered and very little would reach a given point by direct transmission. These two effects would result in a substantial decrease in the amount of thermal energy received.

The decrease in thermal radiation by fog or smoke would be realized only if the burst point is above, or to a lesser extent within the fog or similar layer. If the explosion should occur in moderately clear air, beneath a layer of cloud or fog, some of the radiation which would normally proceed outward into space, would be scattered back to earth. As a result, the thermal energy received would actually be greater than for the same atmospheric conditions without a cloud or fog cover.

In a ground burst, most of the thermal radiation reaching a given point in the peripheral area would have traveled through the air near the earth's surface. In this part of the atmosphere, there would be considerable absorption by the molecules of water vapor, and the extent of scattering by dust particles would be greater than at high altitudes. Therefore, a smaller proportion of the thermal energy of the explosion would reach specific locations.

The degree of protection provided by the intervening atmosphere would be greatly increased by loading the atmos-

phere with absorbing and reflecting agents such as dust, fog, and smoke.

Artificial white chemical smoke acts like fog in reducing the transmission of thermal radiation. A dense smokescreen between the point of burst and a given target would reduce the thermal radiation energy to as little as one-tenth of the amount which would otherwise be received at the target. Smokescreens would thus appear to provide some possibility of protection against thermal radiation from a nuclear explosion.

Factors Affecting Number of Ignitions

Of the total thermal energy striking combustible material, some energy would be reflected, some would be used to reduce the moisture content of the material, and the remaining would produce heat. To cause fire, this energy must be sufficient to raise the temperature of the material from its temperature at the time of attack to its ignition temperature.

Therefore, the number of fires and the extent of the original area of the postattack fires also would vary as to the time of day, season of the year, and the specific weather conditions at the time of attack. Prolonged drought would reduce the moisture content of the materials. The dew at night would increase the moisture content over the daylight content. Low temperature, snow, fog, rain, and high humidity also would contribute to the reduction of the total fire area.

The number of ignitions from the thermal effects would be reduced by hills, buildings, and trees between the explosion and the combustible material. There would be some energy reflected from a straight line by clouds, fog, or dust, but in general, the materials which are shielded from a direct "view" of the burst would escape the primary thermal effects of the explosion. A low burst would result in a considerable amount of shielding. In addition, a low burst over an urban area would create a heavy dust cloud which would absorb a great deal of the thermal energy and might inert the atmosphere to an extent that many fires would be extinguished.

The postattack situation would vary in relation to the specific target area over which the nuclear explosion takes place. A burst could be over a central point of a large metropolitan area, a large forested area, areas containing several widely separate communities, or any of the many other target complexes one can visualize. However, the bomb only furnishes the energy of ignition and the resulting fires depend on the amount, arrangement, and energy of the combustible material within the area itself.

Skin Burns

On a clear day, thermal energy would cause skin burns on exposed individuals at such distances from nuclear explosions that the effects of blast and initial nuclear radiation would be insignificant. The difference between the injury range of thermal radiation and other effects mentioned, becomes more marked with the increasing yield of the explosion.

In considering the probable number of casualties, from thermal effects, the important difference between the effects of the atomic and hydrogen bomb explosions is that the total thermal energy from an atomic burst would be received in a fraction of a second, and the energy received from a low altitude hydrogen burst would be received in several seconds. This difference would make it possible for exposed persons to take some protective actions and probably escape the full thermal effects of the hydrogen burst.

During the high altitude experiments above Johnston Island in July and Au-

gust 1958, it was demonstrated that the thermal radiation from a megaton explosion occurring at 100,000 feet and higher would cause eye injury at great distances. Small burn lesions were produced in the eyes of rabbits 345 miles away, or over an area of 374,000 square miles.

A very high altitude nuclear explosion delivers a great percentage of its thermal energy in about one-tenth of a second after the detonation. As a consequence of this, nearly all of the radiant energy is received by the retina before the eye can be protected by blinking if a person is looking directly at the burst at the time of detonation. This is in contrast to the low altitude detonation of the same yield where the delivery of the thermal energy is slower and where the automatic blinking of the eye provides a measure of protection.

During an attack or an air battle, there could be a number of nuclear detonations at unexpected times around and about populated areas. The need to have a shelter and to get into it is self-evident.

Development of Fires

The postattack fire situation in a large metropolitan area would be expected to follow a general pattern of fires over large areas. There would be a vast area of immediate destruction and a great many fires in the central area, with a lessening number of ignitions as the distance from ground zero increases. If

Damage resulting from a five pound per square inch overpressure in a two-story brick veneer building.

uncontrolled, fires in an urban area would develop into room fires, building fires, block fires, and area fires. Finally the indraft of the main fire and the common chimney effect of a vast thermal column would cause all these fires to join into a single holocaust. (Ed. note: In most cities the worst effect would be area fires. A few of the larger cities have large enough areas of high building density to produce a great, single mass fire or fire storm.)

The fresh air sucked in toward the fire by the updraft of the thermal column would create surface winds of hurricane force. In the Hamburg fire, these winds exceeded 75 miles per hour.† Whether a mass fire would follow the accepted pattern of a fire storm or develop into a gigantic conflagration would depend on the velocity of the surface wind and on the combustible material in the path of the fire.

A fire storm is a phenomenon which involves the almost simultaneous ignition of combustible material over a large area. The initial fires would increase in intensity and eventually unite into a single mass fire which produces a large thermal column, or thermal chimney, which in the absence of a strong ground wind, rises almost vertically. The chimney effect prevents these fires from extending much beyond the original area involved.

A conflagration can start from a single fire. It is a conflagration when many buildings are involved and the fire travels in the direction of the wind. This type of fire radiates an intense heat wave which ignites combustible material and buildings several hundred feet in advance of the main body of the fire. The area ahead of the fire would be showered with thousands of burning brands and embers, cause many additional fires, and tend to make it impossible for firemen to operate against the wind. The only effective stop for a conflagration of this magnitude is an open area sufficiently wide to permit firemen to concentrate their efforts on the protection of the area on the opposite side of the firebreak area, or of sufficient width that the fire will not ignite the combustible material and buildings on the opposite side. Parks, lakes, rivers, wide roads, and open areas provide some firebreaks. Fire resistive buildings with solid walls in conjunction with good sprinkler systems also provide a means of stopping further extension of fire in some areas.

Fighting Small Fires Important

The destruction by fire in Hamburg, Germany, in 1943, frequently has been cited as an example of the overpowering forces which the fire service will have to face. Chief Rumpf's* account of the fire includes the following: "Even if the battle against the fire was hopeless in the center of the gigantic area fires, on their periphery and, in countless individual locations, gradually here and there the fire fighting began to show results. Individual structures, houses, blocks, lines of streets, and whole districts were saved. These would certainly have been destroyed if it were not for the efforts of the fire-fighting forces. Fires were extinguished in 2,427 buildings and extension to other buildings prevented in 635 cases." Chief Brunswig of the Hamburg Fire Department states that "first aid fire fighting, quite apart from fire department operations, saved about 20,000 homes. These in-

†EDITOR'S NOTE: Within 20 minutes of an air raid on Hamburg, Germany in 1943, 2 out of every 3 buildings were afire within a 4.5-square mile area. As fires broke through roofs a turbulent column of heated air rose more than 2½ miles high and 1½ miles in diameter. NFPA Book, Fire and the Air War.

*Chief Hans Rumpf was during the war General-Inspector in charge of the governments' mobile fire department forces and was formerly Chief Fire Officer of Königsberg.

cluded those hit by incendiary bombs or exposed to flying brands."

Time Element Important

The time element would be of major importance in the control of the post-attack fire situation in attacked areas. A fire defense capability must be developed for the rapid extinguishment of the small fires in the peripheral area before they have a chance to develop into area fires.

In 1812, Moscow burned for 5 days, and in 1906, San Francisco burned for 3 days. In World War II, many of the attacked cities were destroyed in a matter of hours. Leading fire authorities agree that the fire resulting from a nuclear explosion, over a major metropolitan area, would reach its peak and begin to die down inside of 3 hours. Generally, individual buildings would be destroyed in about one hour and bulk storage of combustible material and collapsed buildings would continue to burn for days. Where the fire develops into a conflagration, it would continue to burn as long as there is additional fuel.

City Preplanning to Control Fires

The degree of success in containing mass fires would be based on the pre-attack measures, which have been undertaken, for the reduction of the fire potential of each specific target area.

Good building and fire prevention codes should include provisions to prevent the spread of fire from buildings, block, or area of origin. These provisions would require sprinkler protection and water supply, limit frame construction, require fire protection construction, limit the percentage of built-on areas, prohibit wood shingle roofs, limit the amount of combustible material in undivided areas, and compel the removal of rubbish, trash, and dilapidated structures.

Realistic metropolitan planning would result in wide highways, parks, and open areas so located that they would provide invaluable firebreaks.

To meet the need of the nuclear age, metropolitan planning must include the development of facilities for emergency water supply, and to prepare for the full use of all auxiliary water supplies. Failure to make realistic preparation to meet the wartime fire fighting requirements would nullify all other control measures.

Clean Cities Hardest to Burn

The number and extent of the fires, which would result from a nuclear attack, could be greatly reduced by the continued practice of fire preventive housekeeping. Fire preventive housekeeping requires that cleanup actions be performed as an integral part of the everyday basic operation of a home, farm, factory, forest, or community.

To avoid the thousands of ignitions and the rapid development of incipient fires in a nuclear attack, it is vitally important that we *now* eliminate all unnecessary finely divided fuels and really clean up our communities.

Glasgow Whisky Warehouse Explosion

Nineteen Dead

The worst disaster recorded in the peacetime history of the British Fire Service occurred at Glasgow, Scotland, on March 28, 1960. Fourteen members of the Glasgow Fire Service and five of the Glasgow Salvage Corps were killed by an explosion that occurred as efforts were being made to locate a fire in a smoke-filled bonded whisky warehouse. After the explosion, fire spread out of control destroying two buildings and damaging eight others. Approximately 1,043,000 gallons (Imperial) of whisky, 31,000 gallons of rum, and 2,842,000 pounds of tobacco were destroyed. Total property damage is estimated at between $7,500,000 and $11,500,000.

The Whisky Warehouse and Other Buildings

The fire originated in the middle section (No. 1) of a 3-section 6-story and basement building. (See diagram.) Dimensions of the building were approximately 110 ft. by 180 ft. Exterior walls and division walls were brick, floors were wood on wood joists and joists were supported by steel beams on cast concrete columns. There were no openings in the division wall between No. 1 and the bonded tobacco storage section. Openings between No. 1 and No. 2 at each floor level were protected by double fire doors. An open stairway connected all levels of No. 1. In No. 2 an open stairway and two open hoistways extended the height of the buildings.

When originally built in 1892 the building had been designed for flour and grain milling. When Sections No. 1 and 2 were converted into bonded whisky storehouses, about three years before the fire, conversion included replacement of timber beams by steel beams, bricking up all except a few windows and removal of sprinkler protection.

On March 28, No. 1 and No. 2 were loaded to capacity with casks of whisky stored on their sides in each story, three casks high.

Adjoining the north wall of No. 2 from west to east (from Cheapside St. to Warroch St.) were a 3-story office

This photo shows the Cheapside St. frontage of the 3-section building housing bonded tobacco storage (left section) and bonded whisky storage. Note bricked-up window openings in the whisky storage section at right.

This account is based on a Research Report prepared by the Fire Prevention Department of the Glasgow Fire Service. The Research Report with photos and diagram was submitted to the NFPA by Glasgow Firemaster Martin Chadwick, C.B.E., M.I.F.E.

section, a 1-story receipt and delivery area, and the 4-story brick, steel-framed building housing Sections No. 3 and No. 4. Double fire doors were at openings between the receipt and delivery area and No. 3 and were also at openings in the division walls between No. 2 and No. 3 and No. 3 and No. 4.

No. 3 was used for storage and vat filling whereas No. 4 contained eight glass-lined reinforced concrete vats of 55,000 gallons total capacity in the basement beneath the concrete first floor. An exhaust duct with fan was installed to carry alcohol vapors from the vats to outdoors. On the three upper floors of No. 4, whisky was stored in casks.

The 1-story bottling hall (No. 5) had brick walls, wood roof framing, and wooden beams supported by cast-iron columns.

Private Fire Protection

None of the buildings had automatic sprinkler protection. In accordance with insurance company requirements there were portable fire extinguishers throughout the site, and in accordance with the Factories Act the buildings were equipped with a manually operated fire warning system.

Events Preceding the Explosion

At 8:00 A.M., March 28, the whisky storage and processing premises of Arbuckle Smith & Co., Ltd., were opened for a normal day's operations, most of which were in Section Nos. 3, 4, and 5. The only person alleged to have been in No. 1 during the day was the cooper who went from floor to floor tightening bungs, checking casks for leaks, and making repairs where necessary. The premises would normally have been locked up at 5:00 P.M., but on March 28 the foreman decided to stay with two men until 7:30 P.M. to load cases and casks of whisky into trucks, to unload butts (large casks) of whisky, to empty barrels of whisky into blending vats and to move full casks from No. 3 to No. 2. The Customs and Excise Officer of necessity also stayed.

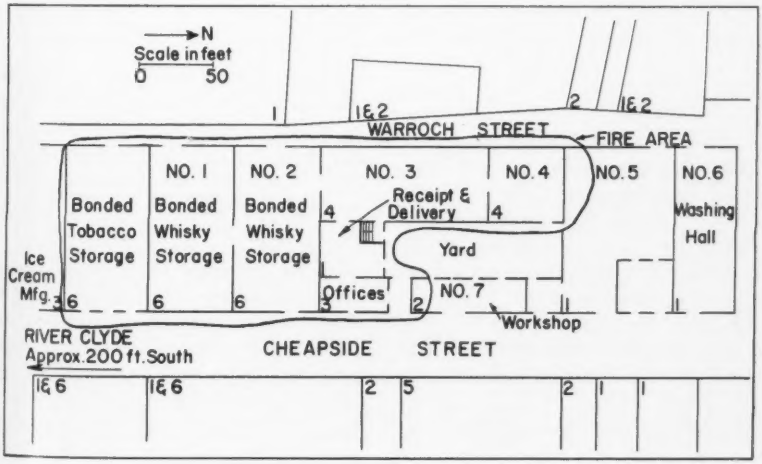


Figure 1. Diagram of buildings involved in the Glasgow bonded whisky storage fire and explosion. The fire originated in the bonded whisky storage Section No. 1.

The whisky storage section where the explosion occurred (Section No. 1) was the middle section of the 3-section building in the approximate center of the photo. Hose streams are being directed into the building from Cheapside St. The exposed steel framing of the building housing Sections 3 and 4 is visible at right.

At about 7:10 P.M. an employee of an ice cream company occupying part of the building south of the tobacco storage section noticed the smell of burning wood and on going into Cheapside Street saw smoke coming from the second story of the bonded whisky storage section, No. 1. Returning to his office he telephoned the alarm, then went to advise the whisky warehouse occupants of the smoke. At about this same time the warehouse foreman noticed a haze in No. 2 but attributed it to fumigation in the tobacco storage section and was first advised of the fire by the ice cream company employee. As the men were leaving the building, the first apparatus was arriving. First alarm response included a ladder-pumper combination, aerial ladder, salvage corps truck, and fireboat (the last mentioned arriving via the River Clyde approximately 200 feet south of the buildings involved — see photo above).

Smoke was then issuing from practically all levels of No. 1. As teams of fire fighters equipped with breathing apparatus were organized and sent to locate the fire, the officer-in-charge at 7:21 P.M. radioed "Make pumps 5."

There were no doorways directly from Cheapside St. to No. 1. As additional apparatus arrived, relay teams were sent into No. 2 in an effort to find their way into No. 1 and locate the fire, but smoke conditions were so bad in No. 2 that they were unable to do so.

In the meantime an aerial ladder had been positioned opposite No. 1 on Cheapside St. and readied to be used as a water tower. Charged lines were taken into No. 2 and an aerial ladder and pumper were dispatched to the rear of No. 1 (Warroch St.) where heavy smoke was escaping. As a fire fighter went to the top of the aerial ladder on Warroch St. to look for flames reportedly seen

through an upper window by a civilian, a group of fire fighters tried to open a metalclad door to the rear of No. 1 that was bolted on the inside. No flames were seen by the man on the aerial ladder, but one of his colleagues saw a glow of fire through a barred first story window at the rear of No. 1. The flame had the purplish-blue coloring associated with burning alcohol and was located at the first story ceiling. "Make pumps 8" was ordered at 7:48 P.M. as a hose stream was directed through the window toward the flame.

The Explosion

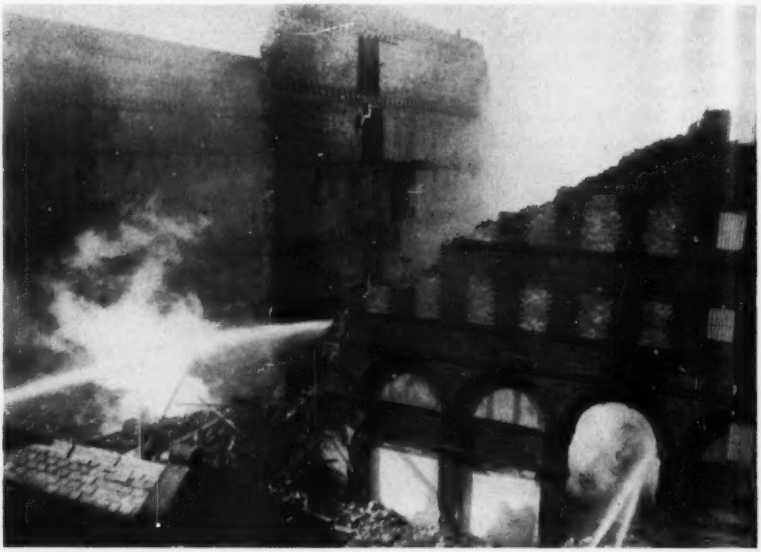
At 7:49 P.M. an explosion, accompanied by a "whoosh" rather than a violent sound, pushed out the Cheapside St. and Warroch St. walls of No. 1 and piled debris on fire fighters and salvagemen in the streets. "Make pumps 10 and send on ambulances" was received at Fire Force Control at 7:50.

Rescuers were able to extricate one fire fighter from the rubble on Cheapside St. and a salvageman from the debris on Warroch St., but further attempts to get to the trapped victims ultimately had to be abandoned due to continuing collapses of wall sections and the rapidly intensifying fire. The fire fighter at the head of the aerial ladder on Warroch St. when the explosion occurred lost his footing but was kept from falling by his safety belt and managed to regain his footing on the platform. Despite serious damage to the aerial ladder and burning alcohol from broken casks cascading among the debris, the aerial ladder truck driver mechanically operated the ladder to bring his colleague to safety.

Events Following the Explosion

The explosion brought down parts of the walls of the tobacco storage section and of No. 2. With the collapse of

Three laddermen lost their lives on Cheapside St. when an explosion pushed a 6-story brick wall into the street. Sixteen lost their lives beneath a similar pile of debris on Warroch St. at the rear of the building.



The firewall with fire doors at openings standing in the center of the photo separated whisky storage Sections No. 1 and No. 2.

flooring, casks burst and spilled their contents. Fed by large quantities of whisky and rum, the fire rapidly intensified and "Make pumps 15" and "Make pumps 20" were radioed at 8:12 P.M. and 8:20 P.M. respectively. As soon as these additional forces arrived and were deployed, a roll call was held from which it was learned that 14 fire fighters and 5 salvagemen were missing.

The fire situation by now had reached alarming proportions. Accompanied by additional collapses and ruptures of casks, fire enveloped the tobacco storage section, No. 1 and No. 2 and was spreading into No. 3 and No. 4. Since the division walls between No. 2 and No. 3 and between No. 3 and No. 4 were intact during the early stages of the fire, it may be that the spread to No. 3 and No. 4 was through doorways at which nonautomatic fire doors had been left open to facilitate movement of casks.

As the fire spread into No. 4, one of the concrete storage vats in the basement exploded violently blowing out the west wall of No. 4 into Warroch St. Fortunately no fire fighters were seriously injured by this explosion.

Due to the congested nature of the area and the narrowness of the streets, particularly Warroch St., there was great danger that the fire would develop into a conflagration. This situation necessitated the deployment of major forces to protect the surrounding property and to arrest the fire spread. In continual danger from exploding casks and burning whisky that poured from the warehouse and flowed along the streets, fire fighters set up water curtains and monitor nozzles and manned hand lines in the streets and at upper windows of exposed buildings. Their ability to keep the fire out of exposed buildings is remarkable considering the fact that the exposed walls or roofs of six buildings facing the fire were ignited.

Working throughout the night, fire fighters stage by stage were able to check the spread and penetrate to the heart of the fire so that at 6:18 A.M., March 29, the fire was under control.

Water supplies at all times were adequate, due in large part to a newly acquired fireboat that supplied 31 hose lines from its position at Anderson Quay on the River Clyde, less than 250 ft. from the fire.

Causes of the Fire and Explosion

Official investigations of the disaster were unable to establish the specific cause of the fire. By elimination of other possibilities, careless smoking and defective fluorescent lighting remained as possible causes.

As for the cause of the first explosion it appears to be the consensus that it was caused by ignition of an explosive mixture of alcohol vapor and air. It is theorized that alcohol vaporized during the fire that preceded the explosion filling No. 1 with alcohol vapors. With most of the windows bricked up and the building otherwise tight it may well have been that there was insufficient air to form an explosive mixture until forced entry was made into No. 1 from Warroch St.

Available reports do not mention another possible explanation that appears plausible — namely, a fire gas explosion. Fire gas explosions (also referred to as back drafts and smoke explosions) have frequently occurred when smoke-charged buildings are opened at lower levels allowing air to enter and form an explosive mixture with the hot products of incomplete combustion inside.

Spacing Automatic Sprinklers

By J. R. Young, Research Engineer
Standards-Laboratories Department
Factory Mutual Engineering Division

Traditionally, the spacing of automatic sprinklers over ordinary hazard occupancies has been based on type of construction. Tests conducted recently lead the Factory Mutual Engineering Division to the conviction that this practice is overly conservative. In particular, the Factory Mutuals feel that the present 90 sq. ft. maximum for nonfirestopped open board-on-joist construction can safely be raised to 130 sq. ft. per sprinkler (the maximum now recognized for noncombustible ceiling construction in the NFPA Standard for the Installation of Sprinkler Systems, No. 13)*. Simplifications of this kind can reduce protection costs.

*The results of this test work have not been submitted to the NFPA Committee on Automatic Sprinklers.

Figure 1. Combination crib-gasoline spray fire used in some of the tests prior to the operation of the automatic sprinklers.

Most sprinklered fire loss experience is with old type* automatic sprinklers, because standard* sprinklers have existed for only a few years. It is universally acknowledged that the old type sprinklers, used according to their installation rules, have done an excellent job. Advantage can be taken of the wealth of proven experience with the old type sprinklers and their performance can be used quite reasonably as a basis for comparing other devices. That is what was done by the Factory Mutual Engineering Division in a series of large scale fire tests with open board-on-joist construction. Results of tests with old style sprinklers, installed in accordance with existing standards as to spacing, were used as the norm against which to compare results of tests with standard sprinklers. The carefully controlled tests were deliberately made severe enough to tax the old style sprinklers and also to provide some challenge to standard sprinklers.

Test Conditions

Comparisons were based on open board-on-joist ceiling panels exposed to reproducible wood crib fires and combination crib-gasoline fires. Old type sprinklers were installed in an 8 ft. by 10 ft. stagger arrangement (sprinklers were spaced 8 feet apart on branch lines

*During 1952 and 1953 sprinklers were redesigned to improve water distribution. The redesign of deflectors was the principal reason for the improvement. The redesigned sprinkler is now known as the "standard sprinkler" and the former so-called conventional or regular sprinkler is known as the "old type sprinkler." See NFPA No. 13, Section 1 for further information. Reference is also made to the January 1954 QUARTERLY, pages 205-212.

and branch lines were spaced 10 feet apart. Sprinklers on any one branch line were 4 feet out-of-step with sprinklers on adjacent lines). Spacing of standard sprinklers was varied upward from a 12 ft. by 7½ ft. stagger (90 sq. ft. per sprinkler). It was found that standard sprinklers, staggered or not, at 130 sq. ft. per head gave protection as good as, or better than, old type sprinklers at 80 sq. ft. per head, staggered.

The board-on-joist test panels were built of well seasoned 2 in. by 12 in. fir joists and 1 in. matched spruce boards, all backed with heavy asbestos paper. Basic panel units were at least 16 ft. by 24 ft. Joists were 1 ft. on centers. Orientation of the joisted ceilings in relation to the test building is shown by Figure 2. Test sections were fastened against the permanent smooth plastered ceiling 15½ ft. above the floor.

The Test Fire

Of the eight large-scale fires reported here, six were run with a crib-gasoline combination exposure (250 lbs. dry wood, 4 ft. by 4 ft. in plan, plus 0.91 gpm gasoline spray). Two were run with a crib alone (360 lbs. dry wood, 4 ft. by 4 ft. in plan). Figure 1 shows a "combination" exposure a short time before fire in joist channels became well developed; sprinklers had not yet operated.

Water Supply to Sprinklers

The water supply to sprinklers was under constant control of the fire pump operator. A pressure gage, mounted at the pump, communicated with a sprinkler branch line near the fire. As sprinklers opened successively during a test, pump speed was adjusted to maintain a preselected pressure at the control point and to insure reproducibility. Location of the pressure control tap in a typical arrangement is identified in the layout on Figure 2.

Sprinkler Thermocouple Placement, Types

Vertical clearance of 6 inches from sprinkler deflectors to joist bottoms was common to all tests but one. In that test (No. 5), the separation was 5

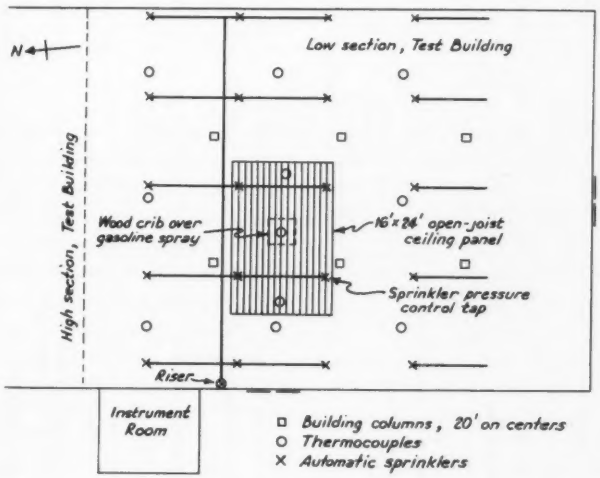
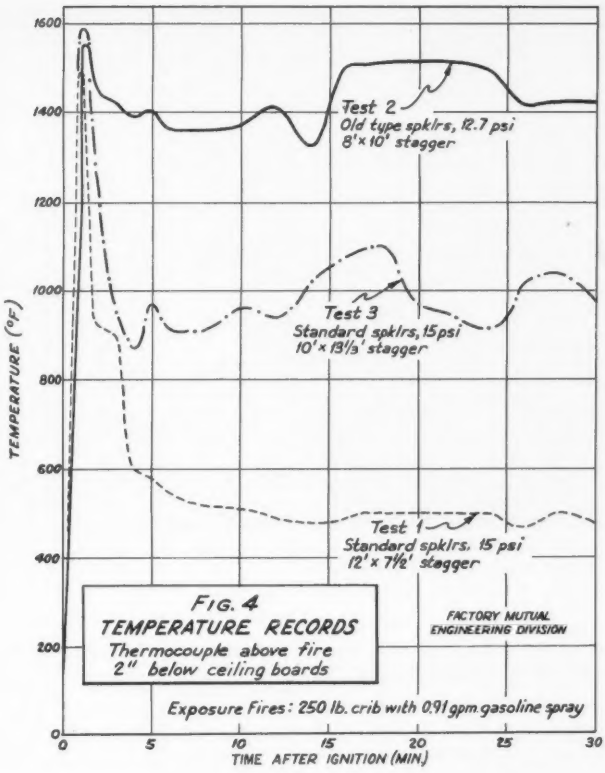


Figure 2. Test area plan showing typical layout for fire test of open-joist construction used in these Factory Mutual tests.

FIGURE 3
Summary of Fire Tests under Open-joist Construction

	Table I — Standard vs. Old Type Sprinklers at Spacings Meeting Respective Rules vs. Standard Sprinklers on Expanded Spacing			Table II — Standard Sprinklers on Expanded Spacing vs. Old Type Sprinklers Meeting Spacing Rules		Table III — Standard Sprinklers on Expanded Spacings vs. Old Type Sprinklers Meeting Spacing Rules			
Test No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Sprinkler Type	Standard	Old Type	Standard	Standard	Old Type	Standard	Standard	Standard	Old Type
Sprinkler Spacing	12 ft. by 7.5 ft., stagger	8 ft. by 10 ft., stagger	10 ft. by 13.3 ft., stagger	10 ft. by 13.3 ft., stagger	8 ft. by 10 ft., stagger	10 ft. by 13.3 ft., rectangular	12.5 ft. by 12.5 ft., square	14.1 ft. by 14.1 ft., square	8 ft. by 10 ft., stagger
Protection Area Per Sprinkler	90 sq. ft.	80 sq. ft.	133 sq. ft.	133 sq. ft.	80 sq. ft.	133 sq. ft.	156 sq. ft.	220 sq. ft.	80 sq. ft.
Fire Location in Plan	Centered between 4 sprinklers	Halfway between 2 nearest sprinklers on adjacent branch lines	Same as Test 2	Halfway between 2 nearest sprinklers on adjacent branch lines	Same as Test 4	Centered between 4 sprinklers	Same as Test 6	Same as Test 6	Halfway between 2 nearest sprinklers on adjacent branch lines
Sprinkler Control Pressure	15 psi	12.7 psi	15 psi	7 psi	7 psi	15 psi	15 psi	15 psi	12.7 psi
Discharge from Sprinkler at Control Point*	22.8 gpm	20.3 gpm	22.8 gpm	15.6 gpm	15 gpm	22.8 gpm	22.8 gpm	22.8 gpm	20.3 gpm
No. of Sprinklers Opened in Fire	10 of 28	23 of 39	12 of 21	16 of 21	12 of 34	15 of 24	12 of 20	20 of 20	23 of 39
Crib Weight Loss	14%	55%	47%	36%	48%	28%	26%	57%	55%
Test Panel Damage Area—Burned Through	0 sq. ft.	17 sq. ft.	0 sq. ft.	0 sq. ft.	17 sq. ft.	1 sq. ft.	trace	145 sq. ft.	17 sq. ft.
Test Panel Damage Area—Charred 1/8 in. or Deeper	0 sq. ft.	83 sq. ft.	7 sq. ft.	92 sq. ft.	57 sq. ft.	10 sq. ft.	10 sq. ft.	105 sq. ft.	83 sq. ft.
Placement of Sprinklers	Clearance of 6.8 ft. from top of crib to sprinkler deflectors			Clearance of 3.2 ft. from top of crib to sprinkler deflectors		Clearance of 6.8 ft. from top of crib to sprinkler deflectors			
Exposure Fire	250 lb. crib with 0.91 gpm gasoline			360 lb. crib		250 lb. crib with 0.91 gpm gasoline			

*Experimentally determined constants of discharge for the standard sprinklers and the old type sprinklers are 5.9 and 5.7 respectively.



inches. Beyond the joisted area, under the smooth plastered ceiling, clearances were uniformly 7 inches.

All sprinklers, whether standard or old type, were equipped with ordinary degree links.

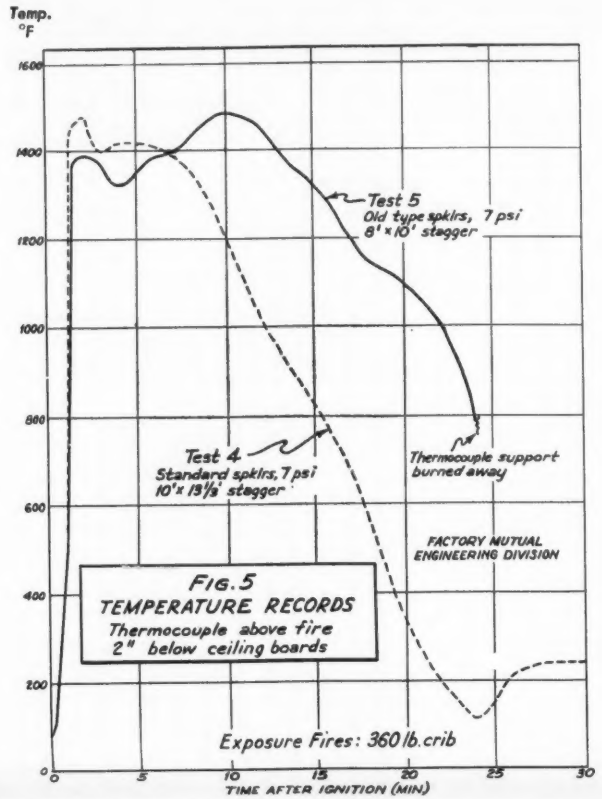
Air temperatures close to the ceiling were sensed by 20 gage Chromel-Alumel thermocouples and were recorded by high speed strip-chart instruments. Thermocouple locations are shown in plan on Figure 2.

Test Procedures

Just before light-off, data were collected on ceiling and crib moisture contents, crib weight, and on various meteorological items (tests were started only when conditions met preset limits). Then, after ignition, observers took running records of such factors as sprinkler fusing times and intensity and spread of fires. Each test was ended 30 minutes after ignition by the use of hose streams on residual fires, if any, and, for combination exposures, the simultaneous shutoff of gasoline spray. The one-half-hour duration was ample for patterns of action to become fully established. Later, ceiling damage was assessed and the crib, after drying, was reweighed.

Exposure Fire
250 lb. crib with 0.91 gpm gasoline
360 lb. crib
250 lb. crib with 0.91 gpm gasoline
250 lb. crib with 0.91 gpm gasoline

*Experimentally determined constants of discharge for the standard sprinklers and the old type sprinklers are 5.9 and 5.7 respectively.


Temp. °F
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
TIME AFTER IGNITION (MIN.)
Test 5
Old type spklrs, 7 psi
8' x 10' stagger
Test 4
Standard spklrs, 7 psi
10' x 13 1/3' stagger
Thermocouple support burned away
FACTORY MUTUAL ENGINEERING DIVISION
FIG. 5
TEMPERATURE RECORDS
Thermocouple above fire
2" below ceiling boards
Exposure Fires: 360 lb. crib

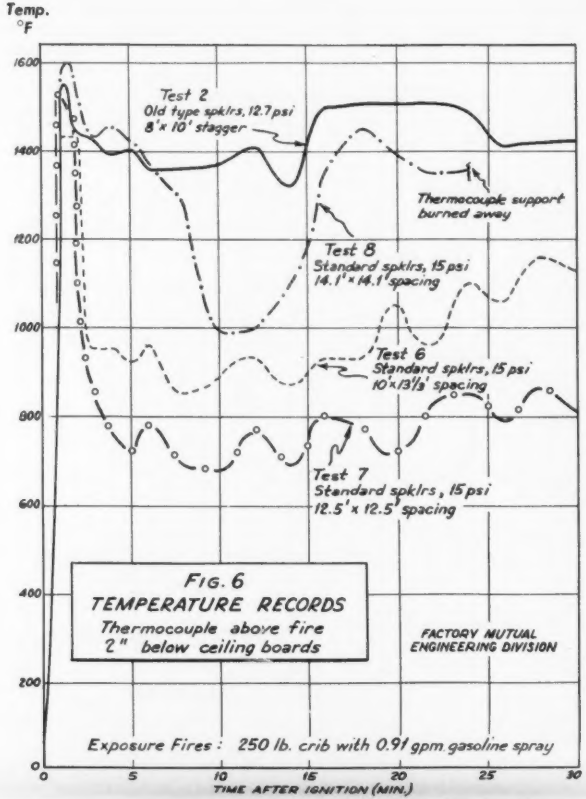

Temp. °F
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
TIME AFTER IGNITION (MIN.)
Test 2
Old type spklrs, 12.7 psi
8' x 10' stagger
Thermocouple support burned away
Test 8
Standard spklrs, 15 psi
14.1' x 14.1' spacing
Test 6
Standard spklrs, 15 psi
10' x 13 1/3' spacing
Test 7
Standard spklrs, 15 psi
12.5' x 12.5' spacing
FACTORY MUTUAL ENGINEERING DIVISION
FIG. 6
TEMPERATURE RECORDS
Thermocouple above fire
2" below ceiling boards
Exposure Fires: 250 lb. crib with 0.91 gpm gasoline spray

Figure 7. The combination crib-gasoline spray exposures caused large volumes of flame to spread along joisted ceilings prior to sprinkler operation. This photo was taken during Test 3 using standard sprinklers on extended spacing.

Test Results and Evaluation

A summary of the fire tests is given in the Tables in Figure 3. The tests are grouped according to related variables. Temperature-time curves, which correspond to the Tables in Figure 3, are shown on Figures 4, 5, and 6. The information contained in the tabulations and in the curves includes four principal criteria for judging sprinkler performance:

1. Extent of damage to construction.
2. Air temperature near ceiling.
3. Crib weight loss.
4. Number of sprinklers operated.

The above items are not readily used singly. Rather, because of the nature and the size of such tests as are described here, these criteria are better looked upon as a whole.

Figure 4 and Table I of Figure 3 offer a comparison of the effectiveness of standard (Test 1) and old type (Test 2) sprinklers, with each style installed at maximum unit protection area (90 sq. ft. and 80 sq. ft. respectively) as recommended in current NFPA Standard No. 13 for this type construction. Under the given conditions, standard sprinklers proved far superior by all the yardsticks used. Table I also has results from a test (No. 3) in which standard sprinklers were spread out to 133 sq. ft., still on a stagger. The standard sprinklers at 133 sq. ft. lost some of their margin of superiority achieved at the 90 sq. ft. spacing, but did a much better job on both construction and occupancy than did the old type at 80 sq. ft. spacing. This latter fact is pictorially evident by reference to Figures 7, 8, 9, 10, and 11.

Another pair of comparative fire tests is listed in Table II, Figure 3. Except

Figure 8. Compare this ceiling fire photographed 2½ minutes after ignition with the conditions shown in Figure 9 below. Old type sprinklers were used in this Test (No. 2) with the sprinklers installed on 80 square foot spacing.

Figure 9. Fire conditions 2 minutes after ignition in Test 3 where standard sprinklers installed on the extended basis of 133 square feet per sprinkler gave better control than did the old type on 80 square foot spacing illustrated in Figure 8.

Figure 10. Fire damage caused in Test 2 where old type sprinklers were used on 80 square foot spacing. The sprinklers limited complete burn-through to 17 square feet with an additional 83 square feet of the ceiling deeply charred.

Figure 11. Fire damage caused in Test 3 where standard sprinklers were used on the extended 133 square foot spacing. There was deep char over only 7 square feet and no burn-through.

for sprinkler types and spacings, conditions for the two tests (including pressure) were the same. Here standard sprinklers, staggered and at 133 sq. ft. per head, again did at least as well as old type sprinklers likewise staggered but at only 80 sq. ft. per head. The Temperature-time curves on Figure 5 reflect much earlier control by the standard sprinklers.

Figure 6 and Table III, Figure 3, deal with a series of tests in which the aim was to adjust the protection area of non-staggered standard sprinklers to the point of getting the same ceiling damage as in Test 2 (old type sprinklers, 8 ft. by 10 ft. stagger). The protection area for equivalent ceiling damage was bracketed by Tests 7 and 8. It will be noted that standard sprinklers covering 130 sq. ft. would compare very favorably with old type sprinklers covering 80 sq. ft.

Conclusion

The Factory Mutual Engineering Division concludes that, for ordinary hazards, a uniform sprinkler spacing of 130 sq. ft. per head is practical regardless of construction. Spacings different from this should depend on occupancy and not on construction.

Fire Hazards in the Shopping Mall

By John C. Thornton, Chairman

American Institute of Architects, Committee on Human Safety

Our modern times introduce new conditions so rapidly that often little thought is given to the hazards they may introduce. This has happened many times in the past few years. In most cases, the hazards are not realized until a tragedy occurs, and then we wonder why we have been so blind.

Supermarkets and super drugstores have become great hazards to life, but we will do nothing about them until there is a fire that kills a large number of people. Thousands of homes have been built with small, high, bedroom windows, creating death traps for the occupants. The author has campaigned against them for years. We are happy that the Building Exits Code (NFPA No. 101) and the BOCA Code (Building Officials Conference of America) now require one window in every bedroom low enough and large enough for escape if there is no outside door from the room.

The new idea of the open plan in homes, schools, and stores, presents problems in smoke hazards. The Los Angeles school fire tests have proven that during the early stages of a fire smoke is usually the principal life hazard in buildings and that open stairways can be the major means of smoke spread through buildings.

In the above-mentioned cases, thousands of structures have been erected before it was realized what hazards had been built into them.

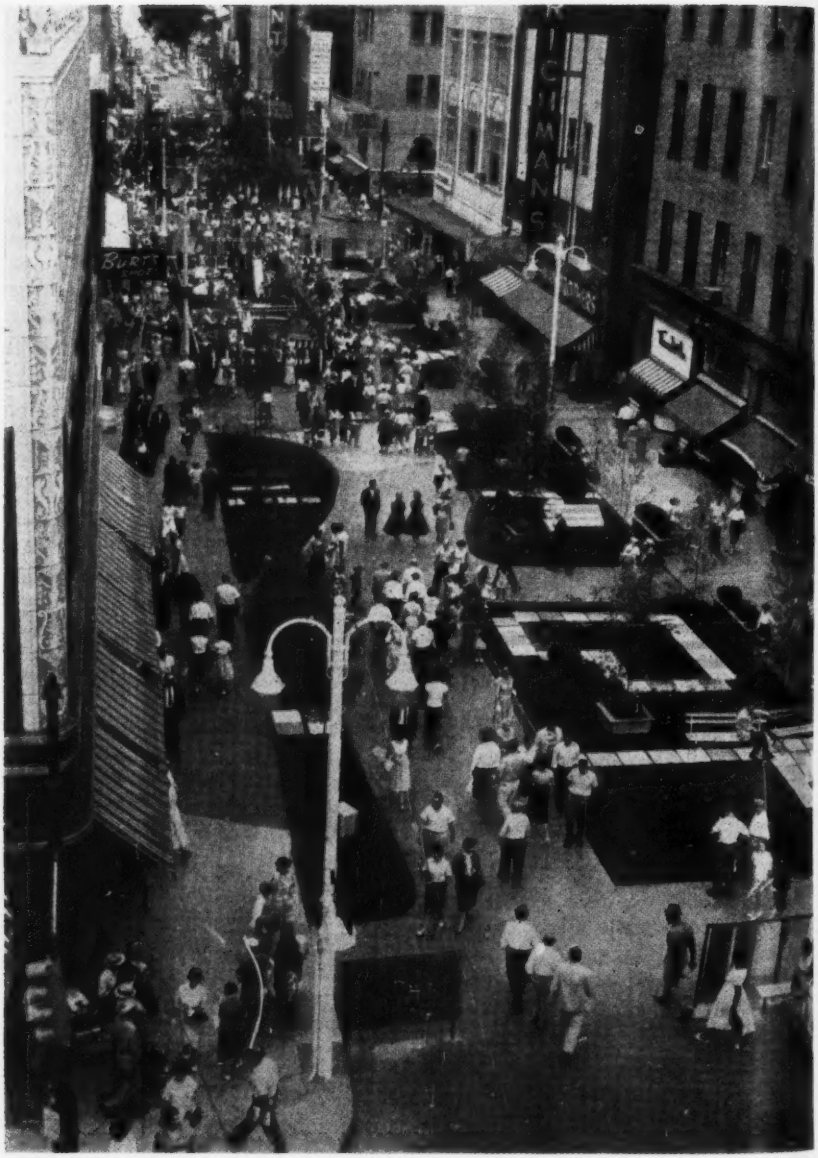
Our attention is now drawn to another possible hazard to life and property — the transition of downtown city streets into malls. We hope that the dangers of these projects are being recognized before it is too late. The usual procedure in this country of going ahead with a new idea and then waiting for statistics to prove it right or wrong does not always appear to be the case in mall design.

Though some of the first schemes did not take care of fire safety, the dangers came to light very quickly, and later designs clearly recognize the hazards.

Pleasant and Convenient Shopping

The building of many suburban shopping centers has so injured downtown business that merchants there have decided that something must be done if they are to remain in business. They believe that the attractive mall, combined with plenty of free parking space is the answer. The problem of the fire service is not to fight the building of these malls, but to aid in their design. Rescue and fire fighting operations should be able to be carried on without undue difficulty.

The idea of a mall is to give shoppers a chance to go from store to store amid pleasant surroundings and in some cases by means of covered walks. While there need not be an actual street, means must be provided for moving fire equipment into and through the mall and for the raising of ladders. The problem will be different in different cities. Each fire department must be on the alert, when plans are made for a mall in its area to be sure that the designs are such that the service will be able to operate efficiently if fire should come.



Toledo tries the shopping mall. This experiment seemed to achieve its purpose, but other factors led to its discontinuance.

In the attempt to solve the many problems that arise in designing a mall, the fire department must work in cooperation with architects and engineers in producing a satisfactory solution.

Problems with Old Buildings

While in modern shopping centers the structures are usually low, the adopting of older downtown streets into malls will doubtlessly present the problem of high buildings, which will demand that there be provisions for the use of aerial ladders.

Watch for False Fronts

If buildings were all to be new when a mall is built, they could be designed for the situation. This is usually not the case, however, and we are faced with the same kind of buildings that are now standing on our main streets, with one difference. Many false fronts will be added to present buildings, which are apt to put an added strain on old walls causing them to fall more quickly in case of fire and endanger the lives of fire fighters. If these false fronts are not firestopped, they can make flues for the spread of fire. Also, present windows will probably be closed, making the structures windowless buildings.

What kind of buildings are we compelled to deal with in a downtown mall? The answer is that there will be many different occupancies, some of which will constitute real fire hazards.

Occupancy Hazards

First, there is the department store. with open stairs, even to the basement, and open moving stairways, usually far from exits. Then we have supermarkets. They are one of the greatest hazards to life today because of the inadequate exits and the possibilities for flash fires. At present Virginia seems to be the only state that is trying to do something about this situation, though there is hope that other states will follow.

There are also many small shops, some with but one exit. These stores often are planned like the one in Bogotá, Colombia, where fire claimed so many lives on December 16, 1958.†

There may be office buildings or hotels with open stairways, or, if closed, discharging into a lobby surrounded by small shops filled with flammable merchandise. Windows would be the only means of escape, so let us hope they are not of the modern variety that defy escape or rescue. Last year in Detroit there was a fatal fire under these conditions.

Windowless Buildings

Windowless buildings, if unsprinklered, soon can become so involved that the fire service cannot reach the flames nor rescue the occupants. There will probably be basements with no access but one flight of interior stairs. Totally enclosed courts are bad enough under any conditions, as it is impossible to get fire apparatus into them, but add to these a mall design, and there is even more of a problem.

Also, in a mall there will be theaters, night clubs, etc., where prompt response is vital to life safety.

Planning Action

What do all these facts signify? They point out that the structures in malls present grave fire problems both for human life and property, and therefore it is necessary that the fact be recognized early in the mall design and steps be taken to ensure that the fire service is not hampered by thoughtless planning.

The first plan is usually a dream, a picture to show what can be done. This plan is intended to sell the idea, but is drawn with little thought of the problems that will arise. At this stage the

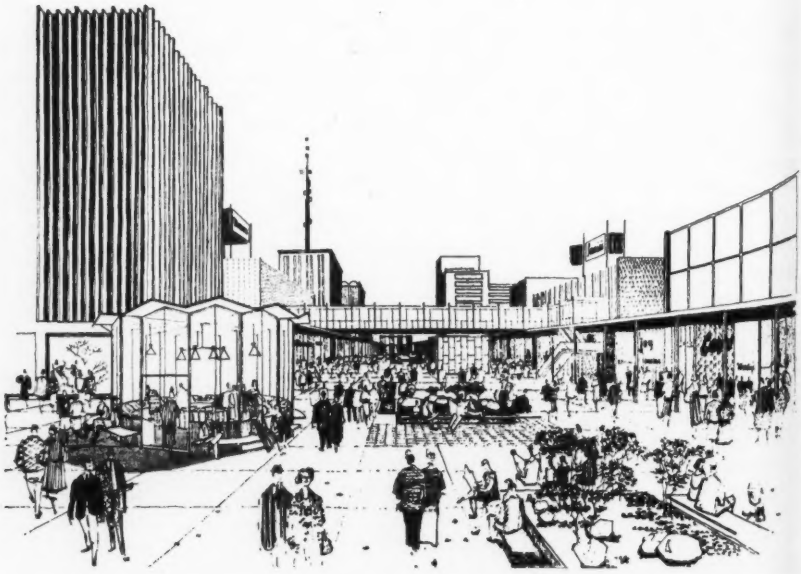
†See report published in the NFPA *Fire News* for January 1959 and October 1959 QUARTERLY, page 143.

fire service is not consulted, but it should try to get into the picture as soon as possible.

Fire Department Access

There are a large number of items to be checked on the plans and in the street. The fire service should be provided with access to at least two sides of each building. In most cases, provision must be made for through traffic. There must be a clear path, at least twelve feet wide, on one or both sides independent of the sidewalks. The path need not be straight, but the curves must have sufficient radius that the longest piece of apparatus can proceed the length of the mall. It is also essential that at corners, apparatus can turn into the mall from the through streets.

Often screens of various sorts are placed at this location projecting part way across the entrance. That this screen does not interfere with access is very important. It should be recognized that the driver is under pressure when answering an alarm, and in a crowded space one of the front wheels may go over the sidewalk, or if it is necessary to back up, a rear wheel may do the same. Sidewalks that are not built for this load will fail. Hollows under sidewalks and extended basements could cause a piece of apparatus to be put out of service and possibly block the way for other trucks. This happened in one city recently. In making the turn, the left front wheel went over the sidewalk and broke through the slab. It is well we have learned this



Sketch illustrating the shopping mall idea. Questions: How about life safety from fire in the windowless buildings shown? What provision is made for fire department access? Will the walkways support the load of heavy fire trucks? All these and other problems would be greatly intensified if the entire mall area were roofed over.

lesson early so that in future designs the problem will be recognized.

Closing of Streets

It has happened that the mall scheme required the closing of a street that should be left open for through traffic by the fire department so as not to delay response to certain buildings where delayed arrival could be disastrous. We know of one case where there is going to be considerable argument. To the uninformed, one street looks as good as another, but fire officers, from their experience, see differently, and they must be on the alert that vital routes are not closed, for time is always the principal factor in a fire situation.

Parking Areas

In most cities interested in building malls, the parking problem must be solved in a satisfactory manner. The realization of the purpose of a mall depends upon sufficient and free parking. Many people will use a dollar's worth of gasoline rather than put a nickel in a nearby meter. The parking areas also must not be far from the stores, since the poor American will not walk more than a block or two. Though he may like to play eighteen holes of golf for the exercise, he gets very tired walking any distance to the store.

Since large parking areas must be provided, they must not, as in the case of many supermarkets, be placed next to buildings where they will handicap fire service. The space next to the buildings should be wide enough so that the fire department can get through, although there are delivery trucks parked along the way. It must also be wide enough for the raising of ladders.

In one city, an adjacent street will take more traffic. The problem will be solved by prohibiting parking. Parking space will be provided at the rear of the present stores with a wide passage between the parking space and the buildings. Owners will probably make this side a second main entrance.

Alarm Boxes and Hydrants

Care must be taken in the plans and construction to have alarm boxes in view from all directions. Fire hydrants, valves on mains, service connections, and Siamese connections to standpipes and sprinklers must also be in full view and there must not be any chance of blocking any of them.

Construction Hazards

All precautions mentioned so far must also be observed as far as possible even while the project is under construction since fires can just as readily occur before all work is completed.

Advantages of Malls

Malls can be built so that they can actually aid fire protection. Fire apparatus will not be hampered by parked cars in front of buildings. Canopies or overhangs, so often a feature in mall design to protect patrons from the elements in going from one store to another, can be used to advantage. If properly designed and of fire-resistant construction, they could be used for second-story escape or rescue and also provide means for attacking the fire at the upper level.

An attractive mall, with parking in the rear, and additional entrances on that side, can have a decided tendency to improving housekeeping and thus reduce the chance of fire. In some locations, the mall may also attract a better class of stores with better fire conditions.

Toledo took fire safety very seriously. While the paths were not straight, they were designed so that they could accommodate fire equipment. This paid dividends when there was a fire and the fire department was able to handle the situation in a satisfactory manner.

Upper Level and Covered Malls

In another city it has been suggested that the mall be at the upper level with the lower level for traffic. This imposes the nice question as to how they expect the fire service to operate. Aerial ladders are not intended for tunnel use. To make the upper level strong enough to support fire equipment would be too costly and then there would be the problem of providing means for the equipment to reach this level.

It has been suggested in another case that the entire mall be covered. Smoke vents in the roof were suggested. This would make the whole area one building. Fire fighting and rescue would be so hampered that there could easily be a tragedy. Complete sprinklering of all buildings would be necessary, and that might not be sufficient. The exit problem is greatly aggravated with a covered instead of an open mall.

Conclusion

In several cities test malls have been constructed for the purpose of finding what problems will be encountered and solving them before it is too late. This may not always be done. It is essential that malls be designed with fire safety in mind. The fire service must be alert to the situation in the early stages of the development of the plan. They know the requirements. The designers may know some of them, but it is too much to hope that they know all of them, and they may not realize that fire safety is so vitally important. When the question of a mall arises, it is the fire service's move.

Extinguishing Agent Developments—

Chemical and Physical Properties of Foam

By A. F. Ratzer, President

Chemical Concentrates, a Division of Baker Industries, Inc.

The liquid used for the production of mechanical or air foam for fire fighting purposes is known by many names such as foam compound, foam-making compound, foam liquid, foam stabilizer, foam concentrate, foam liquid concentrate, liquid foam solution, etc. These names are all used to denote the same generic substance, namely, a concentrated aqueous solution of chemicals which, when diluted in water and aerated, will produce a foam suitable for the extinguishment of fire. The name "foam liquid concentrate" has been chosen for use in this paper since that is the term now considered by the NFPA Foam Committee most nearly to describe this material.

Kinds of Concentrates

There are three main kinds of foam liquid concentrates, known respectively as low expansion, high expansion, and alcohol resistant type. The low expansion type consists of a protein hydrolysate together with organic solvents and metal salts as the foam stabilizer. The high expansion type comprises synthetic detergents of several kinds together with organic solvents and other additives for foam stabilizing purposes. The alcohol resistant type preferably consists of a protein hydrolysate with an organo metallic soap complex as the foam stabilizer; it may, however, consist of a synthetic detergent-alginate mix or a particular type soap solution.

Based on an address by the author at the 64th NFPA Annual Meeting held at Montreal, P. Q., Canada, May 16–20, 1960.

These three different kinds of foam liquid concentrates contain basic chemical differences so that concentrate of one type should *never* be mixed with that of another. Admixture between types may cause precipitation of the active ingredients thus clogging the equipment and rendering the mixture useless. In those cases where precipitation does not immediately occur there may be a considerable reduction in the foaming properties of the mixture and its fire extinguishing properties will be largely destroyed.

The desirable properties of each type of concentrate are related to the purpose for which it is used.

Low Expansion Protein Base Type

Protein base foams comprise those most widely used for fighting oil, gasoline, and other hydrocarbon fires, and represent the standard type employed for the protection of refineries and tank farms, and for aircraft crash fires. This type of concentrate will generally produce foams having expansion ratios of between 6:1 and 10:1 depending upon the type of equipment used, although special apparatus (foam pumps) is available to produce foams of expansions outside this range. The degree of fluidity or stiffness of the foam will vary somewhat according to its expansion and the type of equipment by which it is made, yet in general it should be sufficiently free flowing to move around obstacles and at the same time viscous enough to adhere to vertical and sloping surfaces.

It should have a high order of heat resistance so that it will withstand breakdown from high temperature flame and hot metal surfaces. It should also have good residual stability so that the foam blanket may remain unbroken until after the area has cooled down beyond the danger of reignition.

There are a number of factors which affect the fire extinguishing properties of this type of concentrate. Chemical factors include the particular type of protein used and the extent of hydrolysis, the particular alkaline metal salt of the protein hydrolysate, the nature and quantity of the iron salt, and the type and quantity of the solvent employed. The extent of the hydrolysis will affect both the foam volume and the fire stability of the foam itself. The alkaline metal salt used will affect the viscosity or fluidity of the foam. The iron salt will affect both viscosity and the stability of the foam, and the solvent will affect the freezing point of the concentrate, the expansion of the foam, and possibly also its stability. The presence or absence of added salts may also affect one or more of the above properties.

Variation of the physical characteristics of the concentrate will also have an effect upon its suitability for fire extinguishing and it is in this respect that the pH and viscosity are important. Each particular concentrate has an optimum pH value dependent upon its particular composition. Any substantial variation from this figure may result either in precipitation of active ingredients or reduction in stability of the resultant foam. The viscosity must be adjusted so that the concentrate will remain free flowing throughout its operating temperature range.

High Expansion Type

This type of concentrate finds its main use in those areas where water supplies are limited and must go as far as possible, for spill fires where rapid coverage of the surface is of maximum importance to prevent ignition of other materials, and for exposure protection. The concentrate is designed to produce a foam having a high order of expansion, namely 16:1 to 20:1 based upon the volume of water used. It produces a very fluid foam so as to obtain maximum rate of coverage and flow. The foam has a fairly high rate of water drainage so that it can release its water rapidly for cooling purposes and it collapses entirely to the liquid phase on standing without insoluble residue so as to minimize the problem of cleanup.

Alcohol Resistant Type

The purpose of this concentrate, as its name implies, is to produce a foam which will withstand breakdown by the solvent action of alcohols and other polar solvents. (The commonly used high and low expansion types of concentrate are quite ineffective against these flammable liquids and their foam is broken down immediately on contact with the solvent surface.) Alcohol stability is generally achieved by incorporating in the concentrate a substance which on dilution and aeration will precipitate out in the bubble wall to form an insoluble barrier between the alcohol surface and the body of the foam. This imposes a limitation on the time life of the dilute solution of the concentrate. Obviously, the foam needs to be stable immediately as it is produced, otherwise it will be destroyed by the alcohol. Therefore precipitation of the insoluble barrier material must take place during foam formation. If, however, separation is complete before the dilute solution has been turned into foam, the precipitate will not form a continuous layer in the bubble wall and the foam stabilizing effect will be lost. Therefore it is necessary to reduce to a

minimum the time between diluting the concentrate and forming the foam. In practice this time lag should not exceed 60 seconds or there is a danger that the quality of the foam produced will be impaired. Certain of the foams that are normally alcohol resistant may be broken down if they are applied in such a manner as to cause submergence below the surface of the solvent.

Dilution Rates of Concentrates

When air foam liquid concentrates were first used for fire extinguishing purposes they were generally only available for use at a dilution rate of 5 per cent or 6 per cent of the concentrate in water, also their freezing point was only a few degrees below that of water and they were therefore not suitable for storage or use at sub zero temperatures. Today as a result of extensive research and development work both the protein base and high expansion types of concentrate are available in four different compositions, namely, 6 per cent regular, 6 per cent minus 20 low freeze, 3 per cent regular, and 3 per cent minus 20 low freeze. It may be worth mentioning at this point that the terms 6 per cent and 3 per cent are used to designate the concentration at which the liquids are to be used when diluted in water and therefore the 3 per cent material is effectively double the concentration of the 6 per cent. It is not necessarily the 6 per cent material concentrated to half its bulk since in some cases this would result in a paste rather than a free flowing liquid, but it does have a sufficiently increased concentration of the active ingredients to enable it to be used at double the dilution rate. This, of course, represents a substantial saving in storage and transportation over the original 6 per cent material. The alcohol resistant liquid is still, as yet, available only in the 6 per cent composition.

Storage of Foam Liquid Concentrates

Foam liquids are usually supplied in 5-gallon pails or 55-gallon drums, and these shipping containers are generally suitable for storage provided they are adequately protected on the outside. In many instances, however, it is necessary for the concentrate to be stored in other than the shipping containers as, for instance, in a fixed system, in a large storage tank, in a proportioning tank, or in a tank on a vehicle. In these cases care must be taken to ensure proper storage conditions otherwise there is a danger that the system will not work when called upon in an emergency.

In general, care should be taken to avoid excessive foaming during filling since this will prevent complete filling of the container with liquid and cause aeration with danger of subsequent sedimentation. The tanks should always be filled to leave as small an air space as possible and should either be sealed or vented in such a way that free access of air across the surface is prevented. These liquids are essentially concentrated solutions of surface active chemicals which tend to concentrate at the surface. Only a slight evaporation loss may, under unfavorable circumstances, cause skinning or drying out of the surface layer, particularly if it is in a foamed state. Care should also be taken to ensure that dilution of the contents with water cannot occur during storage since addition of water to the concentrate will upset the balance between the various ingredients and may cause rapid deterioration of the product. Wherever possible the storage container should be so constructed as to provide a minimum exposed surface in relation to its volume and be protected from extremes of heat and cold.

The best material for construction of storage tanks for all types of concentrates is stainless steel. Plain steel or

iron tanks are suitable for protein base compounds, but storage tanks for the high expansion materials should have a protective coating, such as galvanizing, terneplate, or plastic liner. Zinc base coatings are not generally suitable for protein base compounds since they have a tendency to dissolve them.

Pumping the Concentrates

Pumping of the foam liquid may be done by any conventional pumping method providing two precautions are observed. Care must be taken to see that there are no air leaks in the suction side of the pump, otherwise air will be entrained and a very stable foam will be produced. Secondly, there must be no oil contamination within the pumping mechanism since this may destroy the foam properties of the concentrate. Even very small quantities of oil of the order of a few parts per million can, under certain conditions, materially decrease the foaming properties and stability of the foam. This is also true if the water used to make the foam is oil contaminated.

Extinguishing Agent Developments—

Testing of Fire-Fighting Foams

By L. E. Rivkind, Technical Director

Foam Products Division, The Maarl Corporation

It is now generally accepted that fire fighting foams represent the primary agent for the extinguishment of large area flammable liquid fires. Foam provides the only available means for progressive control and extinguishment and continued protection against reignition of vapors by hot metal or other sources of radiant heat and thereby preventing rapid reinvolvement of the entire fuel surface in burning.

But the word foam does not in itself adequately describe the fire extinguishing agent. Foams may be further described or classified in terms of the mechanism of foam formation (chemical or mechanical), the chemical nature of the foaming agents (protein base or wetting agent), in terms of the fuels on which they may be used (hydrocarbons or polar solvents), in terms of aeration devices such as pump foam or aspirating nozzle foam, and even in terms of foam expansion, storage temperature limitations, and recommended use concentration of the foaming agents.

This discussion is limited to the general class of mechanical or air foams regardless of these other qualifying categories, and more specifically to a consideration of the testing of the foam in place, some of the problems encountered in such testing, and an abbreviated report on some of the results obtained in our laboratory.

Based on an address by the author at the 64th NFPA Annual Meeting held at Montreal, P. Q., Canada, May 16-20, 1960.

Fire fighting foam is the end product of a multifunctional system which proportions a foam concentrate and water, pressurizes and aerates the mixture, and finally discharges the foam so formed in a preselected distribution pattern on a fuel surface. The intimate interrelationship of all components is such that a variation in any one will affect the quality of the foam. This somewhat variable product is the real extinguishing agent the physical properties of which may be related to the satisfactory performance of its functions. What are these functions?

Simply stated, foam should be capable of being placed on a burning fuel surface to effect a complete and continuous cover that is resistant to all the destructive conditions to which it will be exposed. In other words it must be placeable and it must be stable in place.

The properties related to foam placement, which may be called the tactical properties, are expansion and fluidity or viscosity. Foam drainage, at both ambient and elevated temperatures and on various fuel substrates is the property the measurement of which may be related to resistance to spontaneous collapse and heat resistance.

The stability of fire fighting foam is a function of four different kinds of resistance, namely, (1) resistance to spontaneous collapse, (2) resistance to thermal radiation or heat resistance, (3) resistance to chemical or solvent attack, and (4) resistance to mechanical disruption.

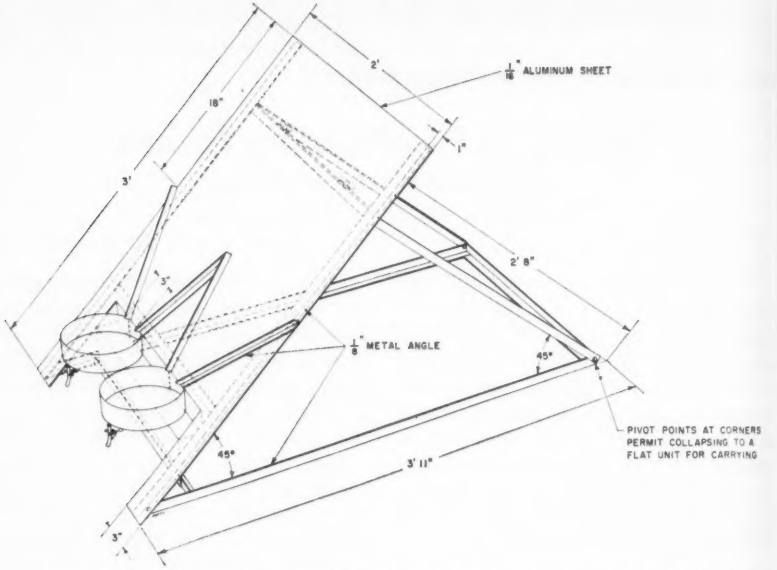


Figure 1. Foam collector developed by the Naval Research Laboratory for field foam expansion measurements.

Test Methods

Foam Expansion Measurements

How can the properties be measured quantitatively? Foam expansion measurement would appear to be relatively simple. Since foam expansion is the reciprocal of specific gravity, we need merely take a sample of known volume and weigh it. Here we run into our first testing problem. What constitutes a sample? A satisfactory sample must be representative of the foam as it is produced and as it is used. The importance of foam sampling on foam analysis cannot be overemphasized. Reproducible sampling problems are ever present in all laboratory work on foam. This is particularly true of the faster draining foams since their properties change so quickly immediately after generation. Indeed, the NFPA Standard on Foam Extinguishing Systems (No. 11)[1] has recently been revised to take this factor into consideration. Figure 1 illustrates the recommended foam collecting board as first used at the Naval Research Laboratory. Foam is discharged against the collector and flows into the sample pans previously positioned. After being struck level, the sample may be weighed. Table I shows the difference in values obtained from a foam sample scooped from the ground as compared with those obtained with this collector. Note that though the foam was produced at the same time from the same nozzle in three different combinations of foam composition and concentration, the measured expansion and drainage values

Table I
Effect of Method of Foam Collection and Sampling

Foam Liquid	Concentration	Foam Expansion		25% Drainage Time (Minutes)	
		Collector Sampling	Ground Sampling	Collector Sampling	Ground Sampling
A	3.5	7.4	8.5	3.2	4.6
A	5.7	8.4	9.0	6.0	7.4
B	3.9	6.7	8.2	3.6	4.8

differ significantly. In each case, the 15 or 20 seconds required to collect samples from the ground permitted some liquid to drain out into the ground thereby giving a higher measured value for expansion and quarter drainage time.

Foam Drainage Measurements

The most widely used method in current use in the U. S. and Canada for measuring foam drainage, described in NFPA No. 11[1], depends on timing the drainage of 25 per cent of the originally contained liquid from the foam, collected in a solid bottom sample holder. Drainage liquid is periodically removed through a small opening at the pan perimeter. Sieve bottom foam sample holders, allowing the foam drainage to be continuously removed, have also been used and are now being considered in revised U. S. Government specifications for foam. It has been suggested that this more closely approximates the conditions in practice, as compared with periodic removal in the NFPA method. Table II shows the numerical differences obtained from these two methods, using two foams of similar expansions but with different drainage characteristics. For foam from nozzle A, the solid bottom pan gives drainage values 68 per cent higher than the sieve while the nozzle B foam is only 32 per cent higher. In fact, even this sieve method does not take into consideration the effect of terrain and accumulation of water at the interface of the fuel and foam. No laboratory method can account for all variations. The quantitative values obtained from any one of these empirical methods should be used with the full understanding that there is no straight line or proportional relationship between these values and the actual rate of drainage under field conditions. They merely serve as a convenient means to characterize foams and do not provide an absolute measure of the time at which a foam blanket has lost 25 per cent of its liquid content.

Table II

Effect of Foam Sample Holder on Numerical Drainage Values

Nozzle	Expansion	Quarter Drainage Time (Minutes) Solid Bottom	(50 Mesh) Sieve Bottom	Ratio Solid/ Sieve
A	10.2	6.02	3.58	1.68
B	9.8	3.18	2.4	1.32

Foam Viscosity Measurements

Measurement of foam viscosity may be achieved with various devices. We have found the Brookfield viscometer, when equipped with a special type of spindle and a strong torsional wire to be a suitable instrument. Figure 2 shows the device as we used it. Note the gear-shaped rotor which "bites" into the foam sample to assure flow of a foam layer with the rotor as it slowly spins at

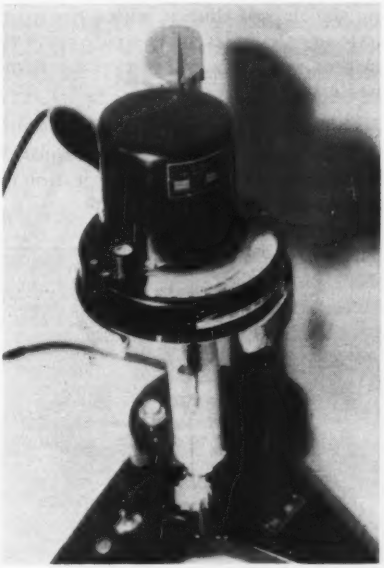


Figure 2. Viscometer used to measure foam viscosity.

a given speed. The torque required to start the spindle rotating is a measure of the resistance to flow and may be read on a scale. Two values may be observed, the initial yield value or critical shearing stress required to start the flow of foam from a static position and the continuous stress, the value at which flow is maintained once it has started. Obviously such an instrument is not for general field use. However, in the hands of trained technicians, valuable information can be obtained.

A somewhat similar instrument has been in use in England[2], but we feel our spindle offers greater assurance of a uniform flow path for foam and there is the further convenience of using a commercially available viscometer.

Foam Thermal Resistance Measurements

Resistance to thermal radiation may be measured by exposing the foam sample on a gasoline substrate to a heat source of known intensity and measuring the elapsed time at which the foam no longer provides an adequate cover to prevent release and ignition of flammable vapors.

This actually measures a combination of foam drainage under the influence of heat and also the rate of evaporation of water from the foam surface.

Figure 3. Heat resistant chamber used by Mearl in their tests.

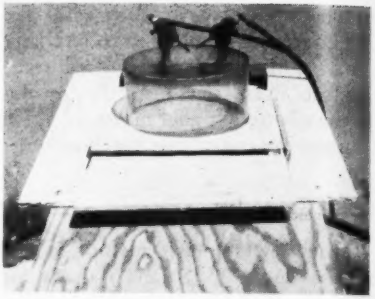


Figure 4. Sparking electrodes to ignite fuel after foam breakdown.

Figures 3 and 4 illustrate one such set-up as used in our laboratory. After the foam sample is collected in the glass sample holder and placed under the heater, a pair of electrodes is positioned. A spark is discharged at 15 second intervals as the foam begins to collapse. When the foam becomes porous enough to permit gasoline vapors to pass through, the spark will ignite them; this time is the end point for the measurement.

Chemical or Solvent Resistance

Technical procedural difficulties have so far prevented us from developing a satisfactory quantitative measure of chemical or solvent resistance though qualitative observations of the rate of foam collapse on a fuel substrate have given useful results.

Mechanical Stability Tests

A type of mechanical stability test for foam has been included in the NFPA Suggested Standard Test Procedures for Aircraft Rescue and Fire Fighting Vehicles Utilizing Foam (No. 412).[3] The burn-back test in this standard suggests that a fire fighter should walk through both fresh and aged foam blankets dragging a four-foot length of 1½-inch hose to observe whether fuel areas are exposed by such mechanical disruption.

Test Results and Foam Property Interrelationships

Following are some of the results obtained in our laboratory with protein base foams using some of these various test methods. These data were used in an attempt to establish foam property interrelationships.

Figure 5 shows the relationship between foam viscosity and quarter drainage time at various foam expansions, using the drainage method as described in NFPA No. 11.

The following conclusions may be drawn from a study of Figure 5:

1. At any given expansion, drainage time increases with foam viscosity.

2. At any given foam viscosity, drainage times increase with increasing expansion.

3. At low expansions (6–7), the relative increase in drainage time is much less than foam viscosity. Hence viscosity measurements are to be preferred for characterizing these foams more precisely.

4. At intermediate expansions (8–12), either drainage time or viscosity measurements can be used to characterize foams.

5. At still higher expansions (12–16), drainage would be the method of choice since the curves in this range are quite steep.

We also studied the effect of foam blanket thickness on heat resistance (R) for foams of various expansions (E) and viscosities (S).

Typical data, plotted in Figure 6, for 1-inch and 3-inch foam blankets, show that:

1. Thermal radiation resistance increases with foam viscosity at any given foam expansion.

2. At any given thickness and viscosity, heat resistance is greater with lower expansions.

3. At constant expansions, thermal radiation resistance increases only slightly with viscosity for thin 1-inch foam blankets but increases more rapidly with thicker foam blankets. (This would suggest that if foam supplies are limited so that only thin blankets are available for covering a spill, the greater ease of obtaining a continuous blanket with more fluid foams may offset the advantage of the inherently greater thermal radiation resistance of rigid foams. This is a tactical problem for which no clear-cut answer has yet been established.)

For the 3-inch blankets, Figure 7 shows that at expansion 8 or more, the radiation resistance increases only slightly with very large increases in quarter drainage time.

We were also interested in how long foam blankets retain their heat resistance. Figure 8 shows that for different expansions and viscosities, even after 20 minutes aging, between 50 to 75 per cent of the heat resistance value for fresh foam is retained by the drained, mechanically unstable foam.

Fire Test Design

So far we have discussed physical property testing and some interrelations among these properties. What about correlating these properties with fire performance? The crux of this problem is to be found in defining the fire, whether it be a spill such as in aircraft crash fires or a storage tank fire. Are we fighting fires on absorptive terrain, with obstructions to flow or is the fuel in a confined area in considerable depth?

In one case, we were attempting to develop a test method which would permit us to evaluate the effect of

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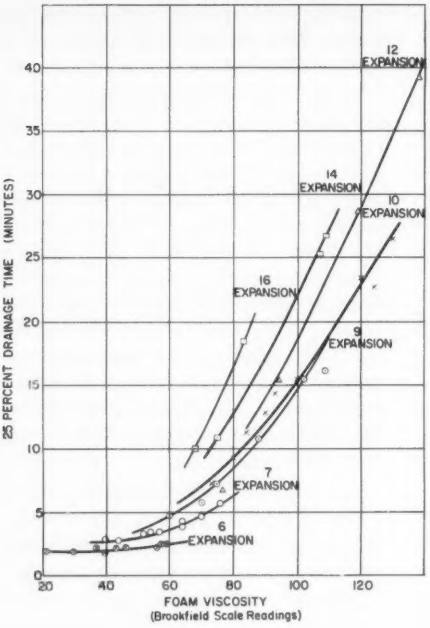


Figure 5. Relationship between foam viscosity and 25 per cent drainage time for foams of various expansions.

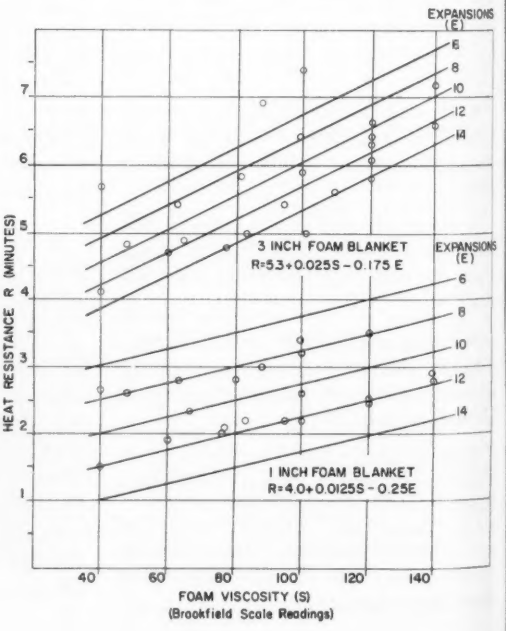


Figure 6. Foams of various blanket thicknesses plotted against heat resistance of foams of various expansions and viscosities. These plots are somewhat idealized and follow the formulas which are based on estimates of incompleted research conducted to date.

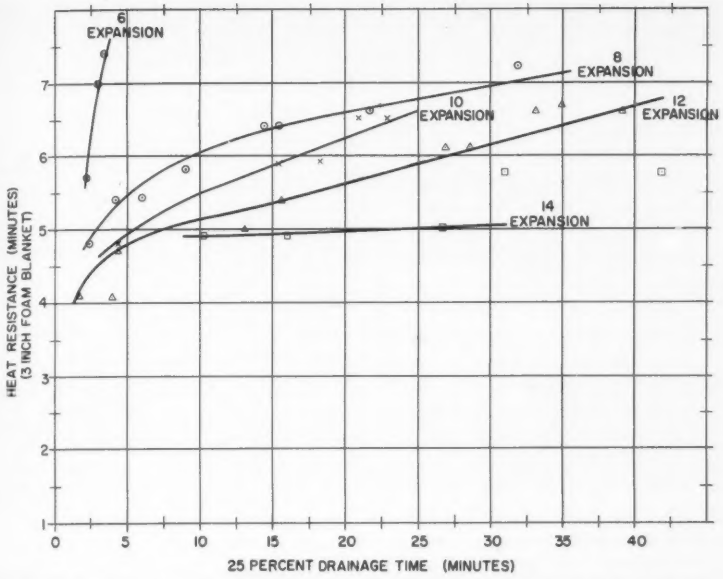


Figure 7. Foam blankets three-inches thick show only slight increases in heat resistance for large increases in 25 per cent drainage time.

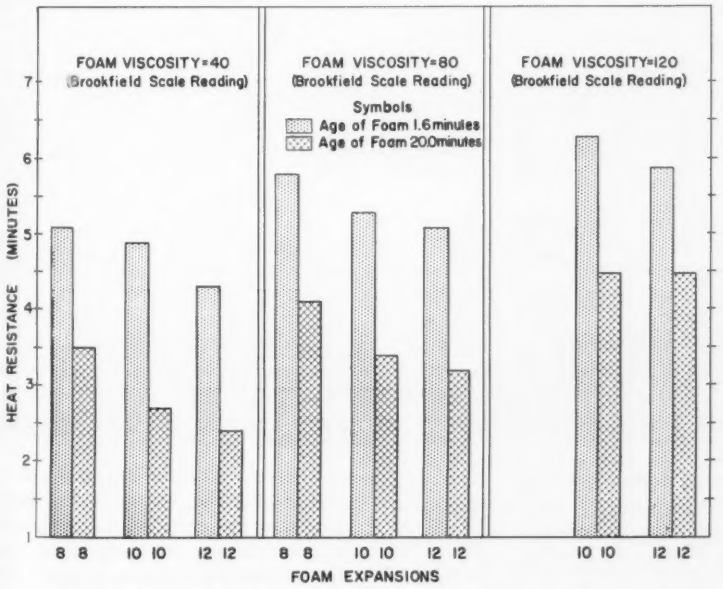


Figure 8. How various foams retain their heat resistance for 20 minutes.

obstructions and their "shadow" effect on the flow of foam and also the effect of terrain. All of these might be factors in aircraft crash fire fighting.

Figures 9A and 9B illustrate our first approach. In the first series of tests, a 10 ft. x 10 ft. area on a concrete slab was surrounded by a mud dike. Half the area was filled with sand and the other half with ¾ in. to 1½ in. crushed rock aggregate. These two areas were to provide differences in absorptive character of the terrain. A barrier consisting of 4 adjacent, open-head, vertical 55-gal. drums (half filled with water for ballast) was placed in a line perpendicular to the direction of foam discharge to provide a shadow and also a major obstruction to flow of foam. Similarly, two rows of fire brick were placed in the diked area, one in front of the drum barrier, the second behind the line of drums. These were to provide minor obstructions behind which "finger fires" might continue to burn and act as potential sources of reignition. Two troughs, 2 in. deep and 10 in. wide running the full 10 ft. length were provided to simulate ruts in which gasoline might collect in depth and burn as pooled fuel areas. The dike wall was 2 in. above the sand and gravel.

Using the same foam concentrate, foam was generated and distributed in a disperse pattern from two different devices. Foam A was quite fluid and had an expansion of 7 and quarter drainage time of about 4 minutes. Foam B, with an expansion of 10.6 and quarter drainage time of 11.7 minutes, was decidedly more rigid.

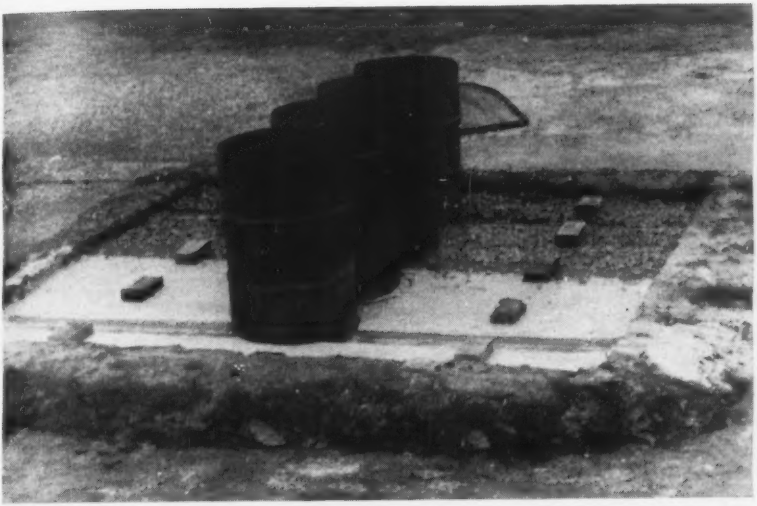
About 40 gals. of gasoline were distributed within the diked area, saturating the sand and gravel sections and allowing fuel to collect in the troughs. After a fifteen second preburn, foam was discharged on the burning fuel, for about 20 seconds, and results observed qualitatively. Figure 10 illustrates typical results in this test. From these tests we learned a few very significant things, showing that this was an unsatisfactory test layout, though it initially appeared quite reasonable.

First, the 2-in. dike was a sufficient barrier in itself to deflect foam at the far side so that its direction of flow on the ground would be reversed and flow towards the foam nozzle. In effect this precluded our observing whether foam would flow around obstacles.

Secondly, in evaluating the effect of porous terrains, we learned that the fuel level should initially be substantially below the surface. Otherwise, the drainage liquor from the foam hitting the hot sand or gravel accumulates quickly, floats the gasoline on its surface, and in effect converts the entire burning area to a shallow "pool" fire. We also saw that the troughs were much too shallow and narrow to permit drawing any conclusions about the effect of direct impingement of foam on the fuel. The effect was overshadowed by the gentle flow of foam from adjacent areas into the troughs. Nevertheless, in this series, we did observe "finger fires" with the more rigid foam and not with the fluid foam.

A second series of fire tests was run using the same foam equipment and foam liquid. However, the burning area was modified. Since the front row of bricks was always covered by flow back of foam from the drum barrier, it was eliminated as were the troughs. The burning area was increased in width to 15 ft. The height of the mud dike used to retain fuel was cut down flush with the level of the sand and gravel in order to avoid any restraint of foam flow. Since the sand area retained much water and gasoline, it was

[continued on page 150]



Figures 9A and 9B. Diked fire test area (10 ft. by 10 ft.) with obstructions for determining fire control capability of various foams on varied types of terrain. The drums were to test how the fuel would flow and the bricks to see if "finger fires" would develop around the bricks. This test procedure appeared satisfactory at first but when tried was found defective, particularly since the diking reversed the foam flow and this did not permit evaluating how the foam would flow naturally around obstructions.

Figure 10.
Results of Gasoline-Fueled Foam Fire Tests in 100 Square Foot Diked Test Area.

Figure 10A. Note how in this test the drum obstructions created "shadow" fires. This was an expansion 7 foam with a 25 per cent drainage time of 4 minutes.

Figure 10B. The bricks created "finger fires" when the foams would not flow evenly and quickly around the obstructions.

Figure 10C. Extinguishment was secured in 20 seconds with this expansion 7 foam, but the test method was not considered satisfactory as reported in the text (page 146).

Figure 11.
Results of Gasoline-Fueled Foam Fire Tests in 225 Square Foot Dike Test Area.

Rigid foam is seen to bank up in front of the drums (used to simulate obstructions) and the fire burns in the "shadow area" even after 55 seconds of foam application.

Another shot of the rigid foam used in this test. It had an expansion of 10.6 and a minimum 25 per cent drainage rate of 11.7 minutes.

removed after each test and replaced with fresh sand in order to get reasonably reproducible fuel distribution.

Fluid foam, applied as previously described for about 25 seconds, completely extinguished the area in front of the drums. The foam also penetrated through the openings formed by the touching rolling hoops of the drums and flowed in behind the drums from the sides covering almost all the remaining area, leaving a slight flicker behind one drum. In a second test, foam coverage was not quite as complete leaving three flickers. In neither case was the effect of sand versus gravel discernible. The performance with rigid foam (expansion 10.6, quarter drainage 11.7 min.) was markedly different. As can be seen from the photographs in Figure 11, taken after 55 seconds, more than double the application time for the fluid foam, there was absolutely no flow of foam into the area "shadowed" by the drum barrier and no passage of foam through the narrow openings between the drums. In this "shadowed" area, the fuel continued to burn unabated though it was extinguished in front of the drums in about 7 seconds. The high viscosity of the foam is apparent from the unevenness of the surface of the foam blanket which piled up to a thickness of 9 to 10 in. in front of the drums.

On walking through this blanket, where it was only 2 in. thick, the foam did not have adequate fluidity to seal off footsteps.

One fire test was also run with still more fluid foam having expansion 6.0 and quarter drainage time of 2.2 minutes. With a pattern width of only 8 feet at a distance of 20 feet from the nozzle, this foam was so fluid that it completely extinguished the 10 ft. x 15 ft. fire, yielded a uniform 1½ in. blanket both in front of and behind the drum barrier, and was readily able to penetrate the openings between the vertical drums.

No attempt was made in this test to assess other factors such as effect of foam viscosity on resistance to submergence in fuel or heat resistance, but only to explore the general fire extinguishing performance of various foams. The test procedure requires further modification and extension to larger scale fires but shows very clearly the tactical value of a fluid foam in being able to overcome "shadowing" by flow around obstacles.

These results are presented only to show how important is the design of a fire test in evaluating foam performance. We by no means are suggesting that the results represent a definitive investigation. Much still remains to be done.

I should like to acknowledge the support of Wright Air Development Division, Wright-Patterson Air Force Base, in some of the research work here discussed, and to acknowledge further the able assistance of I. Myerson and A. Blum of the Mearl staff in planning, directing, and executing various phases of this work.

This discussion has been presented in hope that it will contribute in some measure to further understanding of the problems in foam testing and may serve as a stimulus to further work.

References

1. Standard for Foam Extinguishing Systems, NFPA No. 11, May 1960, Section A–60–20.

2. Clark, N. O., "Study of Mechanically Produced Foam for Combating Petrol Fires," Dept. of Scientific and Industrial Research, Chemical Research, Special Report No. 6, p. 27, London: H. M. Stationers Office, 1947.

3. Test Procedures for Aircraft Rescue and Fire Fighting Vehicles Utilizing Foam, NFPA No. 412, May 1960, Section A–511.

Extinguishing Agent Developments—

A, B, C Dry Chemical Extinguishers

By G. E. Manning, Vice President and Chief Engineer
Underwriters' Laboratories, Inc.

For many years, the fire extinguisher industry has been trying to develop an extinguishing agent which would be suitable for all of the common types of fires; that is, fires in ordinary combustible materials such as wood and paper (Class A), those in flammable liquids (Class B), and fires in electrical equipment (Class C). Recently, efforts have been intensified in the field of dry chemical, which seemed to hold the greatest promise as a so-called "all-purpose" extinguishing agent.

Dry chemical extinguishers have long been recognized for use on Class B and Class C fires. In regard to this type of extinguisher, the NFPA Standard on Portable Fire Extinguishers (No. 10) states: "Dry chemical extinguishers are not effective on deep-seated fires in ordinary combustible materials such as wood, paper, textile, rubbish, etc. (Class A fires), which require the quenching and cooling effect of water for complete extinguishment, but they may be of value for surface fires in small quantities of such material where the smothering effect of the extinguishing agent may be utilized."

The extinguishment of Class A fires has been associated with water and water solutions for so long that one instinctively questions the effectiveness of a powder on such fires. Although water is recognized as an extinguishing agent capable of penetrating and cooling deep-seated fires, it is a fact that the extinguishing potential is a function of the available quantity of the agent, and, in the case of portable hand extinguishers, it must be remembered that rather limited quantities of water are available: 1¼, 2½ or, at the most, 5 gallons. Furthermore, the effectiveness of water for so-called deep-seated fires is reduced by the water or water solution that is wasted in run-off.

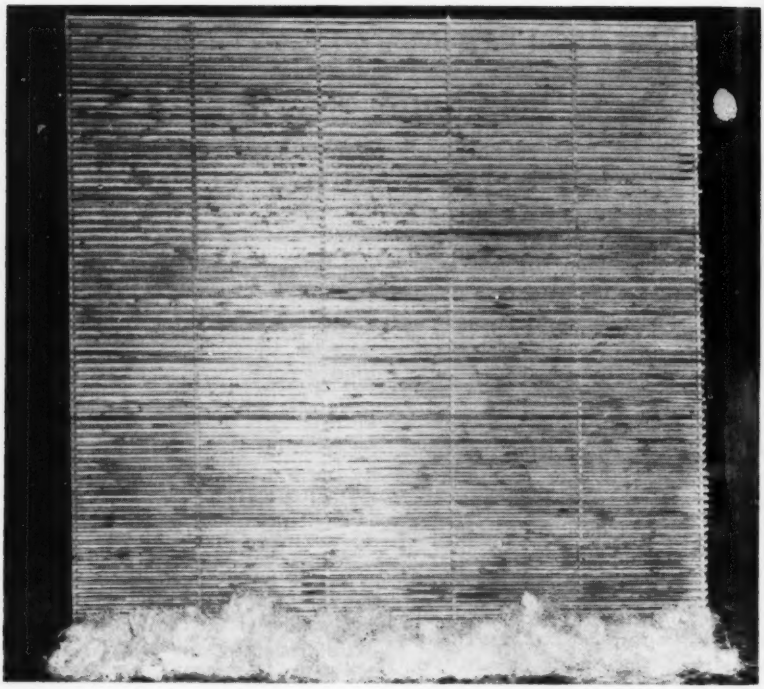
UL Class A Fire Test

It might be well to describe, briefly, the Underwriters' Laboratories tests used to determine the suitability of an extinguisher for use on Class A fires. We have relied primarily on the standard vertical wood panel test for this purpose. The panel, of kiln-dried lumber, is made on a square backing of 1- by 6-inch yellow pine tongue and groove flooring, to which is fastened the lighter material which provides the principal source of fuel for the fire. This lighter material consists of two layers of 1 inch by 1 inch furring strips (of kiln-dried Douglas Fir) spaced approximately 1¾ inch apart. The two layers are separated by similar furring strips spaced 2 feet apart.

For the 2A classification* (the maximum rating for 2½-gallon water or soda-acid extinguishers), a 10 by 10 foot panel is sprayed with 2 gallons of No. 2 fuel oil, and placed in a vertical position with the two layers of furring strips horizontal. A row, consisting of

Based on an address by the author at the 64th NFPA Annual Meeting held May 16-20, 1960, in Montreal, P. Q., Canada.

*See NFPA No. 10 for details on the classification of portable fire extinguishers.



The vertical wood panel test used by Underwriters' Laboratories in classifying Class A extinguishers. This is only one of test procedures used.

5 pounds of bass-wood excelsior, is placed against the base of the panel and ignited by a gasoline fuse. At periodic intervals, 3 similar rows of excelsior are moved up against the base. The result is a vigorously burning panel which is permitted to preburn sufficiently so that the lower furring strips are about ready to collapse, at which time the fire is attacked.

The vertical panel fire test is supplemented by tests using bass-wood excelsior as fuel. For the 2A classification, this test is conducted by spreading seasoned excelsior over a 4- by 8-foot area, to a depth of approximately 12 inches. Gasoline is poured along one edge and ignited. When the flames have progressed to the point where approximately half of the excelsior is burning, the fire is attacked.

Dry Chemicals on Class A Fires

To return to the consideration of dry chemical for use on Class A fires. It was known that experiments and tests with a comparatively new type of dry chemical, obtained from Germany, indicated that it possessed extinguishing effectiveness on Class A fires beyond that of the ordinary sodium bicarbonate base dry chemicals. However, one such chemical, which was suitable for Class A fires, did not perform as well on Class B fires. There were other problems involved, not the least of which was the lack of resistance to caking under moist conditions.

Underwriters' Laboratories, Inc., completed earlier this year an investigation and promulgated its first listing* of dry chemical extinguishers in the 15- and 25-pound sizes for use on Class A, B, and C fires. The 15-pound extinguisher has been classified 1A,16B:C, and the 25-pound size 2A,20B:C. Incidentally, these extinguishers were also found to be effective on magnesium fires. (Editor's Note: To distinguish this material from other "dry chemical" extinguishers this first UL listed Class A,B,C extinguisher is currently being called an "intumescent powder" extinguisher by the firm manufacturing the device.)

The noncaking and moisture repellant characteristics of the new powder were judged under the specifications in the present Standard of Underwriters' Laboratories for Dry Chemical Hand Fire Extinguishers and found to be acceptable. There appears to be no necessity for any change in requirements for these properties insofar as this extinguishing agent is concerned.

It is still too early to determine the effectiveness in service of the A,B,C, dry chemicals compared with presently listed sodium bicarbonate base dry chemical extinguishers on Class B fires. There are certain features about the A,B,C dry chemical which probably will stimulate design changes in the extinguisher as greater experience is gained. As an example, the A,B,C dry chemical, being lighter in density, may require a larger cylinder for the proper quantity of expellant gas.

There is still much to be learned about this "A-B-C" agent, just as in any other new development, but with the same initiative and energy which has brought the sodium bicarbonate base dry chemical extinguishers to their present level of efficiency and effectiveness, we can expect some significant developments in these new agents within the near future.

*See the August 1960 Bi-Monthly Supplement to the U. L. List of Fire Protection Equipment, page 113, for the listing of this extinguisher.

Extinguishing Agent Developments —

Special Dry Powder Extinguishing Agents

By Edmund D. Zeratsky

Development and Design Division

Ansul Chemical Company

Special dry powders have been developed to deal with fires involving combustible metals and certain highly reactive flammable liquids. These powders frequently are the only extinguishing media available to handle these materials. It is important to know the conditions under which each is effective and any limitations on their use. The metal or liquid, the quantity, the physical form, and the nature of the hazard, must all be considered when selecting the proper dry powder and the method of application.

Combustible Metal Fires

Of the many extinguishing agents which are available for use on combustible metal fires, this discussion is limited principally to two dry powder* agents, G–1 and Met–L–X.

G–1 Powder

G–1, a trade name product of the Fyr-Fyter Company is composed of graded granular graphite to which is added phosphorus-containing compounds to improve its fire extinguishing effectiveness. Its composition is such that it can be stored for long periods of time in open containers without deterioration or caking.

G–1 is applied to a fire with a shovel or hand scoop, and it cannot be discharged from fire extinguishers. The heat of the fire causes the phosphorus compounds to generate vapors which blanket the fire and prevent air from reaching the burning metal. The graphite, being a good conductor of heat, cools the metal to below its ignition point.

Met–L–X Powder

Met–L–X, manufactured by the Ansul Chemical Company, is the first dry powder approved for use in extinguishers. It is composed of a sodium chloride base with additives to render it free flowing and cause heat caking. Among the additives are tricalcium phosphate to improve the flow characteristics and metal stearates for water repellency. Particle size is controlled for optimum extinguishing effectiveness. A thermoplastic material is added to bind the sodium chloride particles into a solid mass under fire conditions.

Met–L–X is stored in sealed containers or extinguishers and is not subject to decomposition or change in properties. Periodic replacement of extinguisher charges is not necessary to maintain extinguishing effectiveness. Met–L–X extinguishers range in capacity from 30 pounds for the smallest portable extinguisher to 2,000 pounds for the largest stationary or piped system in use at present.

Based on an address by the author at the 64th NFPA Annual Meeting held May 16–20, 1960 in Montreal, P. Q., Canada.

*As used in this paper the term "dry powder" refers to dry extinguishing agents for use on combustible metal fires. "Dry chemical" as used here refers to those dry materials designed for extinguishing ordinary Class B and C fires.

The technique used to extinguish a metal fire with Met–L–X is to open the nozzle of the extinguisher fully and apply a thin layer of agent over the burning mass from a safe distance. Once control is established the nozzle valve is used to throttle the stream to produce a soft, heavy flow. The metal can then be completely and safely covered from close range with a heavy layer of the powder. The heat of the fire causes the Met–L–X to cake, forming a crust which excludes air and results in extinguishment.

Desirable Properties of G–1 and Met–L–X

Both G–1 and Met–L–X are noncombustible and secondary fires do not result from their application to a burning metal. There is no known health hazard resulting from the use of these two agents. However, the fumes from burning metals in some cases may be toxic. Neither agent is highly reactive with burning metals. Their use will not increase the intensity of a metal fire even if applied in quantities insufficient to achieve complete extinguishment.

Effectiveness of G–1 and Met–L–X on Metal Fires

Fires in dry or oily *magnesium* chips, turnings or castings can be completely extinguished with either agent. The ability of Met–L–X to cling to vertical surfaces makes it especially suitable for magnesium casting fires because it is not necessary to bury a casting in the powder.

The fire hazard of *uranium* is similar to, but more severe than, magnesium. Successful use of both agents has been reported.

Fire tests with *titanium* turnings indicate that pound for pound G–1 is more effective than Met–L–X. This is true whether the turnings are dry or oily. The intense heat from such fires melts the Met–L–X crust and allows air to contact the burning metal. Continued application of Met–L–X to the hot spots is required for complete extinguishment.

Fires involving *zirconium* chips and turnings, coated with an oil-water coolant, can be completely extinguished by either agent. Fires involving moist zirconium chips and turnings are only controlled.

Years of practical experience have shown that *sodium* in depth and sodium spill fires are easily extinguished with G–1 or Met–L–X. It has been found that sodium sprayed or spilled on vertical surfaces can be extinguished by Met–L–X because of its ability to adhere to the molten sodium.

Potassium and *sodium-potassium alloy* spill fires can be readily extinguished with either agent. Fires in depth present a more difficult problem. Because the specific gravity of these metals, when liquefied, is less than that of G–1 or Met–L–X, the powders tend to sink and re-expose the molten metal to air. If a perforated plate is located near the liquid metal surface, it supports the crust formed by Met–L–X which excludes air and extinguishes the fire. Although tests have not been run with G–1 using perforated plates, it is probable that the results would be the same.

Met–L–X is not recommended for *lithium* fires in depth because it sinks into the molten metal and its sodium chloride base reacts with lithium to form lithium chloride and sodium. However, if the application of Met–L–X is continued until more sodium than lithium is present, the resulting sodium fire is easily extinguished. Therefore, Met–L–X is satisfactory for the extinguishment of lithium spill fires.

G–1 is suitable for the extinguishment of lithium spill fires and fires in depth.

To meet the need for a dry powder extinguishing agent that could be discharged from an extinguisher and could successfully extinguish lithium fires in depth as well as lithium spill fires, the Ansul Chemical Company has developed its trade name extinguishing agent, Lith–X. This dry powder is composed of a special graphite base with additives to make it free flowing.

Triethylaluminum Fires

Triethylaluminum ($Al(C_2H_5)_3$), known also as aluminum triethyl, is a flammable liquid that ignites spontaneously in air and reacts violently with water or steam to form heat and a combustible gas (ethane).

Effectiveness of Various Extinguishing Agents

Preliminary small-scale tests were conducted to evaluate the effectiveness of various extinguishing agents on triethylaluminum fires. Water and foams were found unsuitable because of the violent water-aluminum alkyl reaction. Carbon tetrachloride was ineffective. Carbon dioxide extinguished pan fires, but was ineffective on spill fires. Dry chemical and chlorobromomethane extinguished both types of fires, but in almost all cases reignition occurred after extinguishment. When spills were made over beds of adsorbents, the triethylaluminum burned less violently, was more easily extinguished, and showed less tendency to reignite.

Some Uses for Triethylaluminum

Triethylaluminum is under investigation as a complete chemical fuel for ramjet rockets, missiles, and aircraft. Its properties also suggest its use as a reliable means of reignition to eliminate "flameouts" of jet engines. Possible nonmilitary uses include polymerization catalyst, reducing agent, and chemical intermediate.

Extinguishing Action of Lith–X and Met–L–Kyl

The effectiveness of adsorbents indicated by the preliminary tests suggested that Lith–X might be suitable for extinguishment of triethylaluminum fires and also led to the development of a special dry powder extinguishing agent, named Met–L–Kyl by Ansul.

When Lith–X (a graphite base powder) is applied to a triethylaluminum fire, it extinguishes only by adsorption. Its initial application has no effect on the extinguishment of the flame and consequently enough must be applied to absorb all of the triethylaluminum. Lith–X should preferably be discharged as a low velocity, soft stream to prevent splashing of molten metal. The Ansul Met–L–X 30 (30 pound capacity) extinguisher is suitable for discharge of Lith–X since it possesses these discharge characteristics.

Met–L–Kyl is a dry powder composed of a mixture of a bicarbonate base and an activated adsorbent. Its flow characteristics are such that it can be discharged effectively from an Ansul 30–D (30 pound capacity) dry chemical extinguisher. The extinguishing action of Met–L–Kyl on a triethylaluminum fire differs from that of Lith–X in that the initial application of Met–L–Kyl extinguishes the flame and the continued application adsorbs the remaining fuel and prevents reignition. A dry chemical type extinguisher is suitable for Met–L–Kyl application since during initial application the extinguishing action of Met–L–Kyl is the same as a dry chemical extinguishing agent on a flammable liquid fire.

Results of Tests with Lith–X and Met–L–Kyl

Tests were conducted on pan fires (fires in depth) and on spill fires. In these tests the agents were used to put out fires involving 10 pounds (1.439

gallons) of triethylaluminum in a 2¼ square foot metal pan and 10 pound spills covering an area of 50 to 60 square feet on metal test pans.

In these tests both Lith–X and Met–L–Kyl successfully controlled and extinguished fires in depth and spill fires.

Met–L–Kyl reacted slightly with the triethylaluminum during application but the reaction did not hinder the extinguishment. Eight pounds of this agent were required for each pound of triethylaluminum when in depth, and 10 pounds of agent per pound of triethylaluminum for spill fires. The ratio of pounds of Lith–X to pounds of triethylaluminum required for complete extinguishment of the test fires (both in depth and spills) was 7 to 1.

Faster control of the fires is achieved with Met–L–Kyl than with Lith–X because of Met–L–Kyl's initial flame extinguishing action. A considerable amount of the Met–L–Kyl is carried away by the updraft of the fire during the initial flame extinguishing phase which accounts for the greater amount of Met–L–Kyl required for complete extinguishment.

Extinguishing Agent Developments—

Recent Navy Research on Dry Chemicals

By Richard L. Tuve,
Head, Engineering Research Branch
U. S. Naval Research Laboratory

In the last five years some significant advances have been made to improve dry chemical fire extinguishing agents. These improvements have widened the usefulness of this type of agent. This report of work conducted on this subject at the U. S. Naval Research Laboratory will review the development of "foam compatible" dry chemicals and tests on potassium bicarbonate dry chemical, now called "Purple-K-Powder" by the Navy.

Foam Compatible Dry Chemicals

Back in 1945 a fire chief in California had the foresight to employ dry chemical on a gasoline spill fire which had been partially extinguished by the use of mechanical (air) foam. He reasoned (and rightly so) that the exceedingly fast, but temporary, extinguishing power of dry chemical should be coupled with the relatively slow, but "permanent" extinguishing power of foam. Much to his amazement, the chief had the unique opportunity of watching his foam blanket melt away as if touched by a magic wand after the dry chemical had been applied. The result was complete reinvolvement of the surface of the gasoline in fire.

Similar undesirable foam-destroying results from the use of dry chemicals were reported to us from various areas, even from outside of the U. S. Navy,[1] until, in about 1949, we did some test-tube and very small scale research on the problem at NRL. By simple isolation of each component involved in the mechanism (foaming agent or foam liquid concentrate, hydrocarbon fuel, sodium bicarbonate-type dry chemical, dry chemical coating material, and heat or flame), we found that a very powerful surface physical force was being exerted on the walls of the bubbles in the foam by the "polar" molecules of the zinc or magnesium stearate type of dry chemical coating agent. This slippery white crystalline powder is normally insoluble in water or foam liquid concentrate. However, in the presence of gasoline or hydrocarbon (which acts as a solvent for both the concentrate and the stearate to a degree) and when heat is introduced, the heavy metal stearates function as foam breakers.[2,3]

This was discovered by "test-tube" research, from which we graduated to small 23-inch diameter test fires, and then to 3-ft. by 3-ft. comparison fires employing critical rate* addition of foams with the compatible dry chemicals under examination. This later became a specification test (with some improvements) for Navy procurement of compatible dry chemical.[4]

These tests and the results of other experiments definitely proved to us that if dry chemical was to be used with complete safety in fire-fighting operations where foam is the primary defense against fires in hydrocarbons such as gasoline and jet fuel, we must have a dry chemical completely free of stearates or other foam destroying materials

Based on an address by the author at the 64th NFPA Annual Meeting held in Montreal, P. Q., Canada, May 16-20, 1960.

*The critical rate is the rate of agent application below which extinguishment is not possible.

used as coating agents. At about this same time (1956) the Boreham Wood Fire Research Laboratory in England took note of the breakdown of air foams where dry chemical was used simultaneously.[5,6]

In 1956 a military procurement specification (MIL–F–19563 (Aer)) for dry chemical was written by the Bureau of Aeronautics, incorporating our requirements for foam compatibility along with other requirements for noncaking, free flowability, submicron* particle size and other important characteristics. Since that time the Department of Defense alone has very successfully utilized over a hundred thousand pounds per year of the sodium bicarbonate type foam compatible dry chemical.[7]

*Less than 0.001 millimeter.

Revised Testing Procedure

Within a year after publication of the first specification for foam compatible dry chemical we learned of some of the difficulties being experienced by manufacturers and other testing groups in duplicating the outdoor 3-foot comparison test fires for compatibility using foam. Variable weather and wind problems were being experienced during testing. Errors in personal judgment of percentage area involvement in fire were showing up.

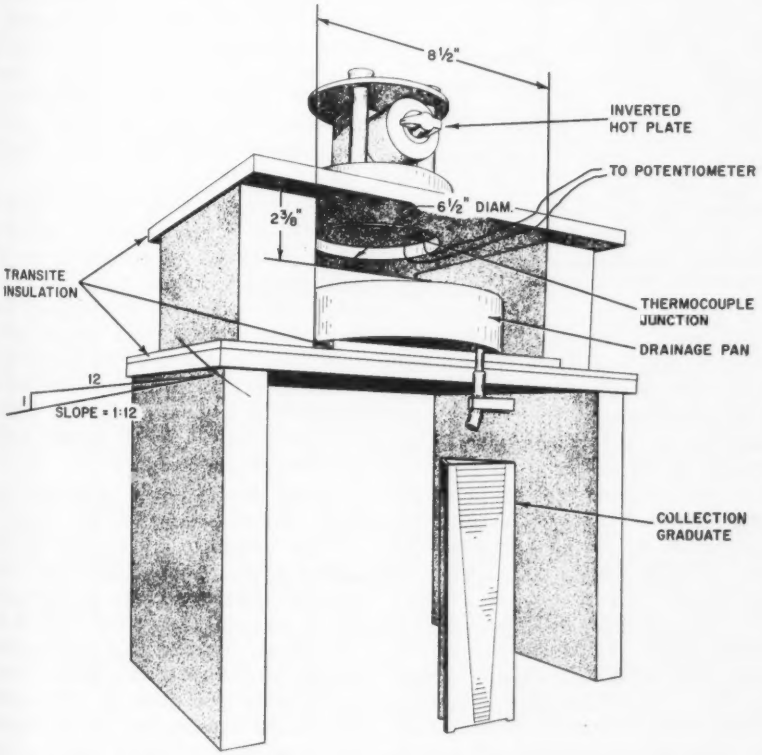


Figure 1. Heat exposure test setup for foams in contact with dry chemical.

The final result of some careful laboratory test research on the problem was a test to show the effect of exposure to heat and dry chemical on foam drainage rate.[8] Here a carefully prepared foam sample is exposed to attack by both heat and dry chemical. No fuel or flame is involved so the test can easily be performed indoors (see Figure 1). The rate of liquid drainage of the foam is markedly accelerated by the presence of incompatible powders (see Figure 2). The validity of this test has been further supported by British investigators.[9]

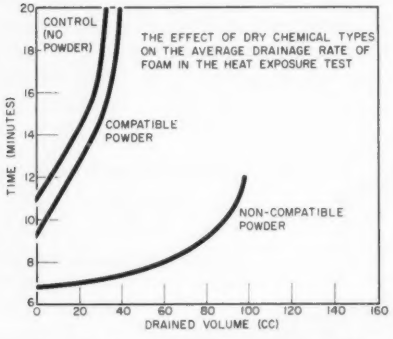


Figure 2. Typical curve of test results of heat exposure test method.

The test resulted in such definitive limits of foam breakdown that we were able to unravel a new puzzle having to do with the foam itself. Ever since our discovery of the detrimental surface activity of dry chemical in 1949, we have been instrumental in putting a certain amount of pressure on the manufacturers of dry chemical to develop a new formula which was compatible with foam. Of course one of their defensive arguments was that the foam manufacturers should develop a foam concentrate with compatibility toward dry chemical! We had always remained adamant that it was the burden of the dry chemical manufacturer to make the step toward compatibility.

With the improvement of our test for compatibility we found the first concrete evidence that certain foam concentrates were much more vulnerable to attack than others even though their raw material formulas were closely identical and they had passed all requirements in the JAN–C–266 Specification.

This problem is slowly being ironed out — but not without a little tongue-in-cheek, "I-told-you-so," attitude on the part of the compatible dry chemical producers.

Potassium Bicarbonate Research

The use of compatible dry chemical has been very successful over the last few years in conjunction with air foam, especially in crash-rescue fire extinguishment areas in the Navy, but *everything* is capable of improvement. This leads to the story of the research and development of *potassium* bicarbonate type of compatible dry chemical which has become better known as "Purple-K-Powder."

Back in 1928, Thomas and Hochwalt reported in the literature[10] some new hydrocarbon fire extinguishing test results using alkali metal solutions. They found that solutions of potassium carbonate were much more potent liquid fuel flame quenchers than the similar sodium, or lithium salts. This work became the foundation for the highly successful Class A and B loaded stream portable fire extinguisher.

It was only a simple deductive step from this work to raise the question, "What would the comparative efficiency of the other alkali metal compounds (than sodium) be for fire extinguishment purposes when used in the *dry chemical* state?" This question was propounded in 1951 but it was not until seven years later that the first report was issued showing the fire extinguishing superiority of potassium bicarbonate base dry chemical powders.[11]

To describe briefly this research, we first procured some potassium bicarbonate crystals of a high purity. These were milled and ground and treated with free-flowing agents so that the final potassium bicarbonate was almost exactly the same as commercially available sodium dry chemical as to particle size distribution, screen analysis, flow characteristics, and specific surface area. When discharged from identical extinguishers at identical pressures, the rate of discharge of the potassium was identical to that obtained in ordinary commercial practice with sodium bicarbonate dry chemical.

The test fire used for comparison of results of sodium vs. potassium was an indoor square pan fire, 3-ft. by 3-ft. in size, with 1½-inch high sides, containing 3 liters of fresh fuel for each fire test. Manual operation of a fan-shaped dry chemical discharge orifice was found to be most efficient after many failures of standardization of fixed discharge over the burning area. Rates of constant dry chemical application or discharge were varied to achieve criticality of rates for extinguishment using the two powders on the 9 sq.-ft. fire.

Figures 4 and 5 illustrate a very important point in fire extinguishment

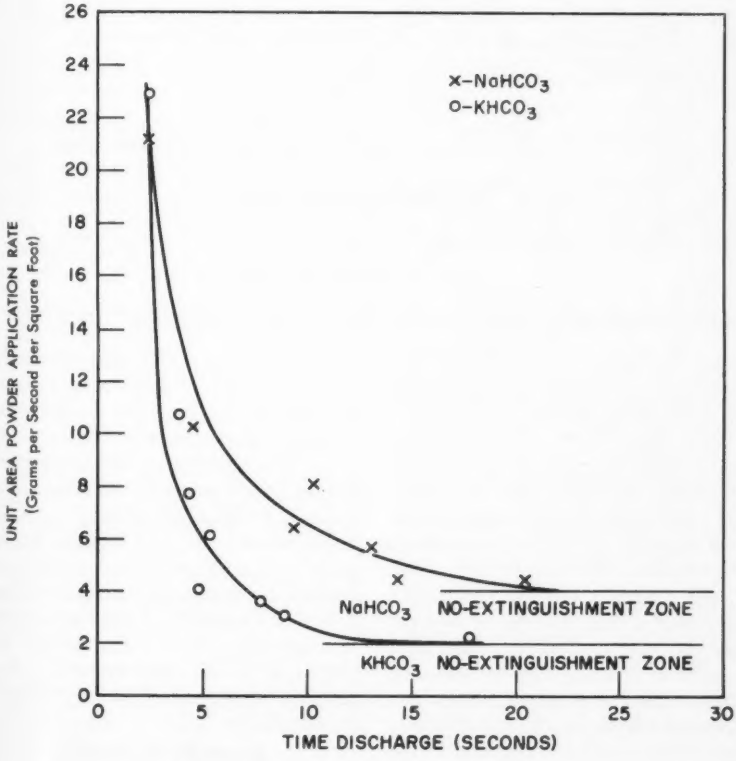


Figure 4. Plot of sodium bicarbonate ($NaHCO_3$) and potassium bicarbonate ($KHCO_3$) dry chemical results on a gasoline test fire at varied rates of application on a discharge-time basis.

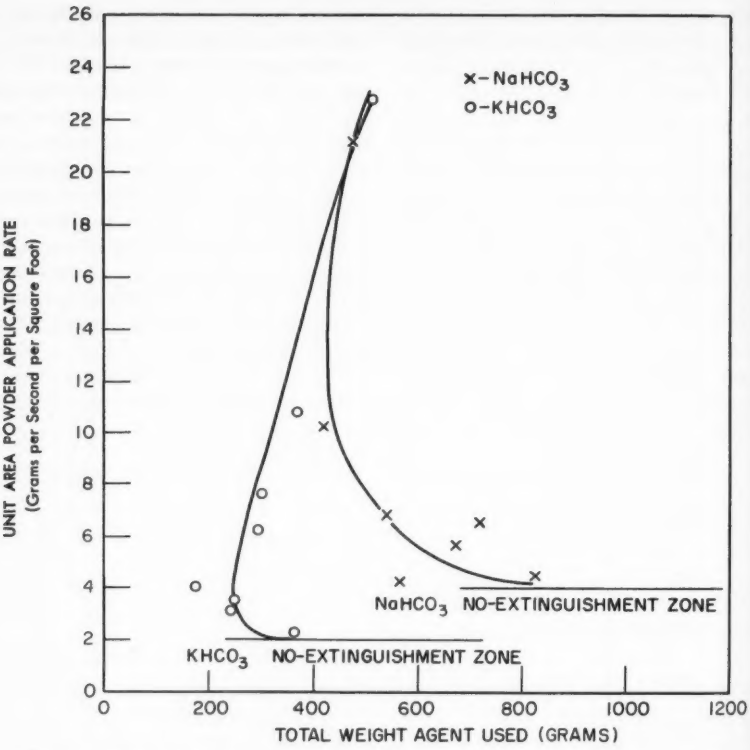


Figure 5. Similar plot to Figure 4, but using total weight of dry chemical discharge as basis.

testing. The basic or fundamental efficiency of an extinguishing agent can only be judged at *critical rates of application* to a flame front. Where excess agent is available for extinction, no comparative efficiency can be determined. The critical application density rate of 4 grams per second per square foot for sodium bicarbonate dry chemical, and a similar critical application density rate of 2 grams per second per square foot for potassium bicarbonate dry chemical in these 9 sq.-ft. fire tests, indicates that the potassium bicarbonate functions with double the efficiency of the related sodium compound at the critical rates.

The testing proceeded in scale to outdoor fires increasing in size until criticality of area rate of application of agent was reached at a constant discharge rate of 300 grams per second. Here again the 2 to 1 extinguishment efficiency of the potassium over sodium was preserved, sodium bicarbonate failing to extinguish below rates of 5.3 grams per second per square foot and potassium below rates of 2.7 grams per second per square foot. These comparative efficiency rates of application have been further supported by small scale tests that have recently been reported by the Bureau of Standards.[12]

Summary on $KHCO_3$

Many more tests of a comparative nature have been run at the Naval Re-

search Laboratory since this work. It is difficult to assign a numerical value to the superiority of potassium bicarbonate over the standard sodium dry chemical in *all* the areas of fire extinguishment practice, but we are quite confident that a real stride forward has been made and we hope our work will be advanced by others more skilled in the application of new materials to the profession of fire fighting.

A new specification[13] has been originated by the Bureau of Naval Weapons covering the required characteristics of foam-compatible potassium bicarbonate type dry chemical and one of the first applications of this higher efficiency dry chemical will be in the Navy's portable air-lifted dry chemical extinguisher employing a 400 lb. spherical container of dry chemical and two 75-ft. length light-weight hoses with nozzles discharging 175 lbs. per minute each. This air-lift unit is designed for two purposes; on-the-station fires where a high volume discharge is needed and ordinary vehicles can reach the fire, and off-station fires where the unit can be air-lifted, with its rescue crew, to a fire not readily accessible with motorized apparatus and heavy crash trucks.[14]

Figure 6. Four hundred pound dry chemical extinguisher for truck transport or air-lift to inaccessible areas.

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(13) Military Specification MIL-F-22287 (Wep) 15 Dec 1959, "Fire Extinguishing Agent, Potassium Dry Chemical."

(14) BuAer Instruction 11320.16 (Aer-SE-743) "The Navy Airlift Type Dry Chemical Fire Extinguisher", 14 Aug 1959.

Extinguishing Agent Developments—

Carbon Dioxide Extinguishment Tests

By E. W. Cousins, Chief Research Engineer
Factory Mutual Engineering Division

A research project to investigate factors involved in extinguishing fires with carbon dioxide was undertaken during 1959 by the Factory Mutual Laboratories in cooperation with a group of system manufacturers. This paper reports on the progress made to date on the test program.

The research was started by a question by one Factory Mutual engineer as to whether a carbon dioxide system would actually put out a fire using the maximum lengths of pipe permitted by the existing NFPA Standard on Carbon Dioxide Extinguishing Systems (No. 12). He gathered together some pipe, nozzles, cylinders, and tried it. The fire was not extinguished at the first trial nor at a second. Almost everyone's reaction was "well, if it won't work at that length, what length will it work at? Let's find out." This approach would, of course, answer the question of the effect of pipe length, but would leave unanswered *many other questions*, such as the effect of cylinder temperature, of nozzle orifice size, of cylinder valve size, and of nozzle spacing.

A much more desirable approach would be to try to understand the entire process of extinguishment taking in the whole system from the cylinder to the fire. Offhand, it would seem that the process of extinguishment with carbon dioxide is quite simple. All that is needed is to exclude the oxygen long enough for the flames to go out and an additional period long enough to allow cooling. The statement of the problem is simple; it is in the accomplishment that the difficulty arises. Early in a preliminary investigation, it was found that no one was really sure what factors determine whether or not the fire would be put out. There were any number of ideas, but it turned out that these ideas were not backed up by any test records.

A two part research program was proposed to the manufacturers of carbon dioxide extinguishing equipment. The first phase would be to find the factors which determine whether or not a fire is extinguished and the second part would be to find how to get the carbon dioxide to the fire in such a way that the extinguishment factors would be satisfied. After careful consideration, the five largest manufacturers of carbon dioxide systems decided to finance this research project cooperatively.

Carbon Dioxide Flow vs. Water Flow

Again, the problem is simple to state, but the nature of carbon dioxide makes the solution difficult. When figuring friction losses in or discharges from a fire protection system using water, there may be some question as to the interior condition of the pipe or the effect of fittings, but at least you know that if you put 10 gpm into one end of the pipe you get 10 gpm out at the other end. With a carbon dioxide system, you may put 10 gpm in and find that you have over 100 gpm at the outlet. This makes the computation of friction losses very complex, and to compound the complexity, friction losses, rate of flow, and fluid volume vary with the storage pressure.

Based on an address by the author at the 64th NFPA Annual Meeting held at Montreal, P. Q., Canada, May 16-20, 1960.

In the same way, the flow of water through an orifice depends only on the type of orifice, the area, and the pressure; while with carbon dioxide it varies not only with the type and area of the orifice and the orifice pressure, but also with the storage pressure and with the fluid density just ahead of the orifice.

In a carbon dioxide extinguishing system, liquid carbon dioxide is drawn from a container, passes through a pipe line, and is discharged through an orifice to the atmosphere. Since the discharge time is ordinarily short, on the order of a minute or less, the liquid carbon dioxide does not have time to pick up heat from the surroundings. As the liquid carbon dioxide passes through the pipe, it loses pressure by friction, and vapor forms. If the pressure at the end of the discharge line is say 750 psi absolute, the carbon dioxide at this point consists of about 20 per cent vapor and 80 per cent liquid. If the pressure at the discharge orifice were 150 psi absolute, it would be 50 per cent vapor and 50 per cent liquid. When it is discharged into the atmosphere, the discharge consists of 75 per cent vapor and 25 per cent solid. Thus, we are not dealing with a substance in a constant state but one which is continually changing. The problem is not simplified by the fact that the percentage of liquid and vapor cannot be determined by such simple measurements as pressure or temperature. There are various ways of measuring either the density or the heat content but none are readily adaptable to a system where these are changing rapidly.

Test Equipment

Since the advent of the atomic age, a method of density measurement has become available which operates continuously and rapidly. It operates on the principle that the denser the material the less radiation from a radioactive source passes through the material being tested. We obtained assistance from Tracerlab in modifying one of their standard Beta gauges to measure the density of carbon dioxide.

Figure 1 shows diagrammatically the arrangement of instrumentation and

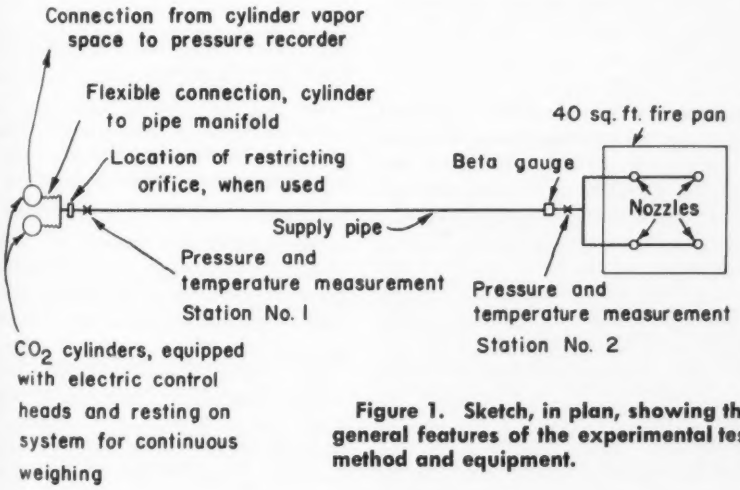

Connection from cylinder vapor space to pressure recorder
Flexible connection, cylinder to pipe manifold
Location of restricting orifice, when used
40 sq. ft. fire pan
Beta gauge
Nozzles
Supply pipe
Pressure and temperature measurement Station No. 1
Pressure and temperature measurement Station No. 2
CO_2 cylinders, equipped with electric control heads and resting on system for continuous weighing

Figure 1. Sketch, in plan, showing the general features of the experimental test method and equipment.

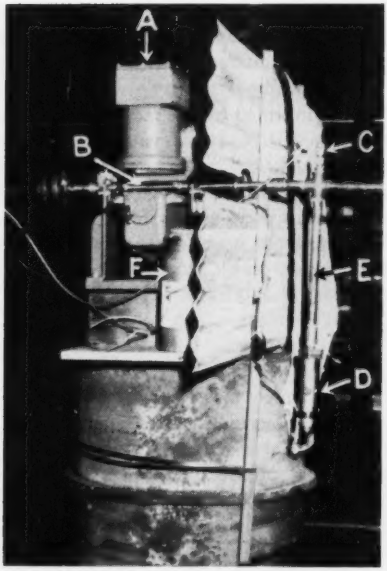


Figure 2. The Beta gage (A) is mounted at the end of the test section of the pipe line. The radioactive source is in this unit and the carbon dioxide passes through a special thin walled steel tubing section (B) between the source and the detector. A thermocouple (C) is provided for measuring the temperature of the carbon dioxide and a Baldwin pressure cell (D) for pressure measurement. A long pipe nipple (E) is filled with kerosene to protect the pressure cell from the low temperature. The thermos (F) is the cold junction for the thermocouple.

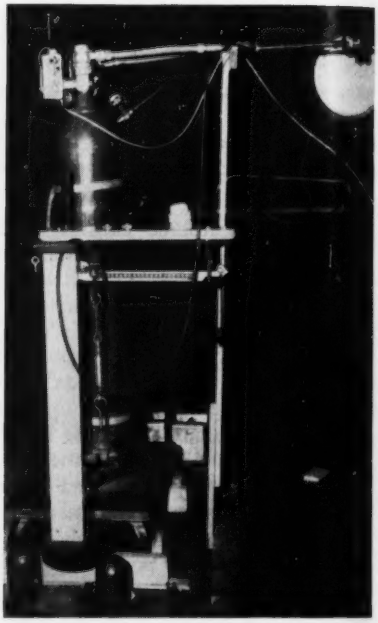


Figure 3. The supply carbon dioxide cylinders mounted on a scale. The scale arm is connected to a Baldwin load cell so that a continuous measure of the weight of the cylinders could be recorded electrically. The circular (Foxboro) pressure recorder in the background is connected to a cylinder to make a record of the vapor space pressure.

equipment. The cylinders equipped with electric control heads are mounted on scales arranged for continuously recording the weight. They feed through flexible connections to a manifold at the beginning of the supply pipe. There is a connection to the vapor space of one of the cylinders arranged for continuous pressure recording. At Station 1, at the beginning of the supply pipe, pressure and temperature of the CO_2 are measured and also at Station 2 at the end of the supply pipe. At Station 2 the density is measured. From Station 2 the CO_2 enters the nozzle manifold over the fire tank. Figures 2, 3 and 4 further illustrate the test setup.

The test fire was a 40 sq. ft. pan with a 2 inch depth of fresh gasoline and 6 inches of freeboard. The fire was allowed to burn for 30 seconds before the extinguishing system was tripped.

Pipe lengths used were 21 ft. with no elbows, 101 ft. with 3 elbows and 181 ft. with 7 elbows. Distributing systems of 4, 6 and 9 nozzles were tested.

Factors Necessary for Extinguishment

Tests 1 and 2 had been planned to give high rate of discharge with the hope that the fire would promptly be extinguished. It did not work out that way.

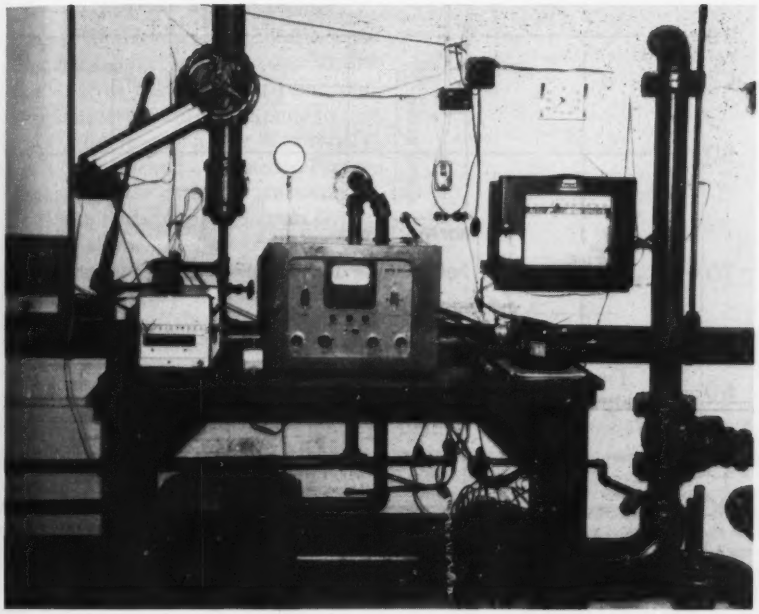


Figure 4. The control cabinet for the Beta gage is located in the center of the table and indicates on the meter in the center of the panel. The output is also connected to the high speed recorder mounted on the wall under the clock. Just to the left of the Beta gage control cabinet is the recording galvanometer which records the pressure and temperature at the beginning and end of the test section of piping, and the weight of the cylinders.

Why had the fire not gone out? It could not have been because of too low a rate of flow. Obviously, there was some other factor involved. One suggestion was that it might be exit velocity of the carbon dioxide from the horn. Certainly there is a minimum velocity which will carry the gas down through the updraft of the fire and it could be that there is a maximum velocity above which either the liquid in the tank would be splashed over or so much air drawn in that the fire would not go out. To test this theory, the number of nozzles were increased from 4 to 6 and the size of the individual nozzle orifices was reduced. The fire was extinguished promptly which indicates that the horn velocity is a very important factor.

Tests were carried on, varying the rate of flow and the horn velocity by means of orifices in the pipe line, by changes in length of the pipe line, by cylinder storage temperatures, and by nozzle orifice size. The results plotted against rate of flow and horn velocity are shown in Figure 5. The heavy line separates the extinguishments from the failures and defines the region within which fire will be extinguished and outside of which it will not. Regardless of cylinder temperature or of all the other flow limiting variations, if the point falls in the extinguishment region, the fire is put out; if it falls outside, the fire is not extinguished. Thus for this particular setup, the factors necessary for extinguishment of a fire were determined.

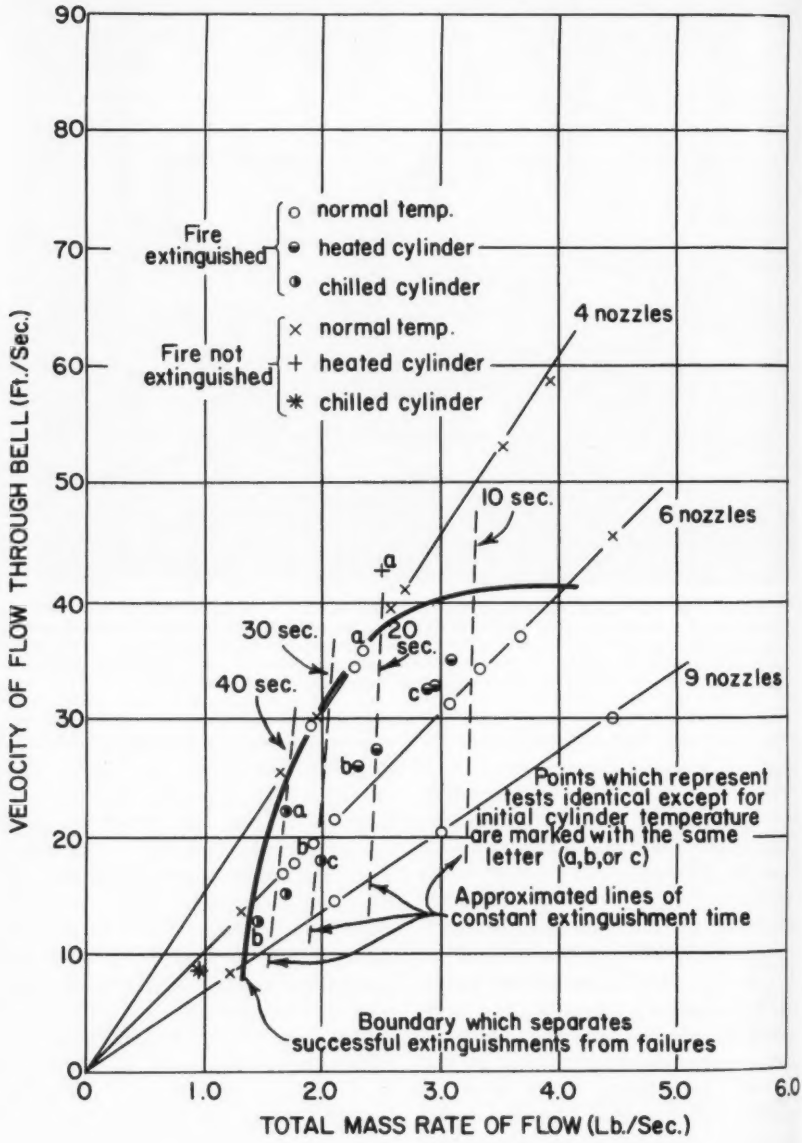


Figure 5. Velocity of flow through bell (horn) of carbon dioxide nozzle vs. the mass rate of flow on a gasoline test fire in a 40 square foot pan. There was a clear division between those tests which failed to extinguish the test fire and those which succeeded.

Carbon Dioxide System Design

Having found what was necessary to extinguish the fire, we then come to the second part of the project: to find out how to deliver the carbon dioxide to the site of the fire in such a way as to satisfy the extinguishment requirements. Figure 5 illustrates that there are two conditions which must be met: (1) that is, the proper total rate of flow and (2) the proper velocity of vapor through the horn. The problem is further divided into (3) the flow through the nozzle orifices, (which determines the horn velocity and the total rate of flow) and (4) the design of the supply pipe to deliver CO_2 to the orifices at the proper pressure. J. C. Hesson* had investigated both of these subjects; pipe flow, as a thesis for a Master of Science degree from Illinois Institute of Technology in 1953, and the flow through orifices for a Doctor of Philosophy degree from the same institution in 1957. The existence of these data gave assurance that this research project could be carried out with a reasonable amount of testing.

During the fire tests temperature and pressure were measured at the entrance and end of the test pipe section. The rate of flow through the pipe, and the density of the carbon dioxide at the end of the pipe had been measured so that it was possible to compare the pressures and rates of flow predicted from Hesson's formulas with those actually measured and to compare the density with those computed thermodynamically. It was felt necessary to make the flow comparisons because Hesson's tests were made with so-called low pressure carbon dioxide, that is, from a tank held at 300 psig and 0°F while these tests were made at pressures from about 400 psig to 1400 psig.

*See "Carbon Dioxide Flows in Pipes and Nozzles", by H. V. Williamson, in the July 1959 NFPA QUARTERLY, pp. 70-82.

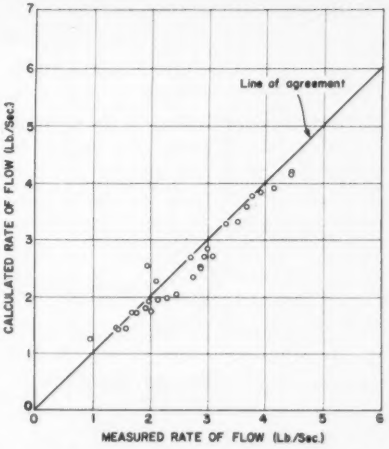


Figure 6. The measured vs. the calculated rate of carbon dioxide flow with no restricting orifice in the supply line showing general agreement, with the calculated rates slightly greater. This difference could be taken care of with a coefficient if it were thought necessary.

Figure 6 shows a comparison between the calculated rate-of-flow and the measured rate-of-flow for all the tests in

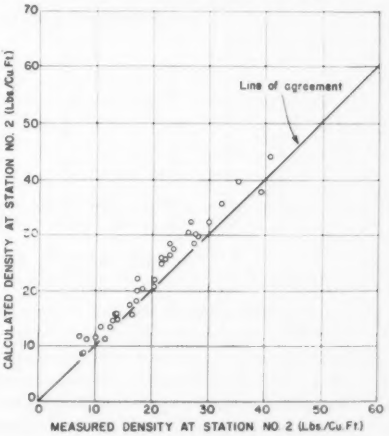


Figure 7. The measured vs. the calculated carbon dioxide density in pounds per cubic foot as measured at Station 2 in the tests discussed (see Figure 1). The fact that the calculated density of carbon dioxide agreed with that measured directly by the Beta gage showed that little heat is picked up by the CO_2 while flowing in the pipe.

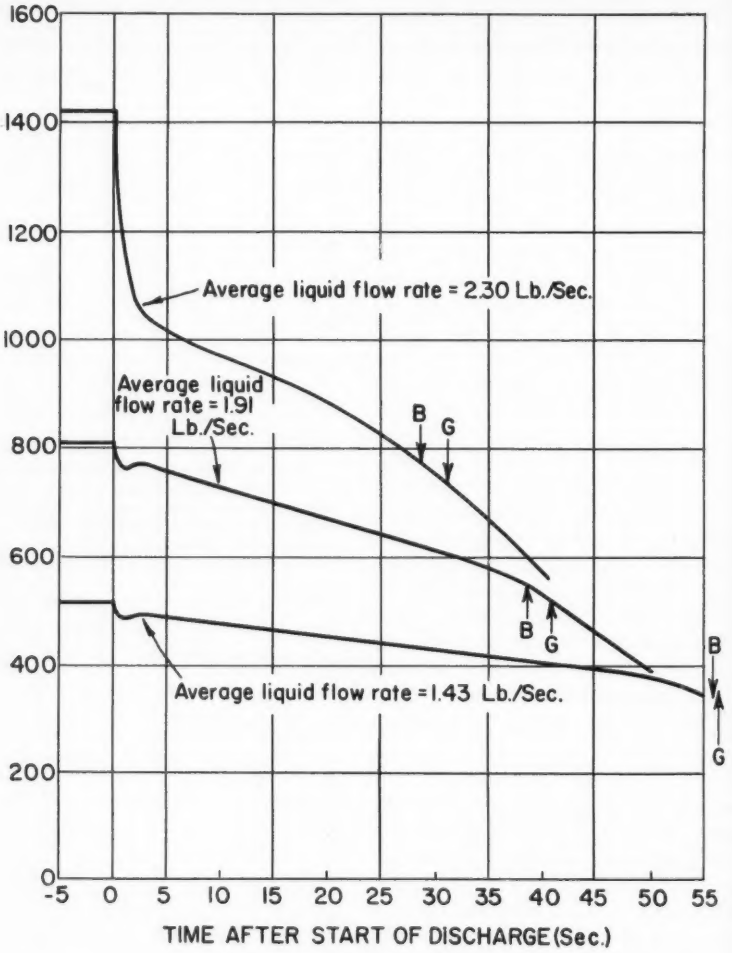


Figure 8. Cylinder pressure vs. time after start of carbon dioxide discharge. This shows how flow rates vary with various initial cylinder pressures. The top curve illustrates the variation of pressure with time for a cylinder at about 100°F. and an initial pressure of 1425 psig, well above the critical temperature of carbon dioxide (87.8°F). The pressure dropped very rapidly to the critical pressure at which point part of the contents became liquid and then the liquid flow took place normally. The other two curves show the pressure-time variation on the same system but with cylinders at initial pressures of 810 psig, (temperature about 70°F), and at 520 psig. Points marked G indicate where there was an abrupt change in the sound of the nozzle discharge (indicating a transition from liquid to pure vapor flow) and points marked B indicate where there was a more or less abrupt change in the slope of the pressure curve at the beginning of the test pipe section. In these tests, six No. 5 nozzles were used with the supply pipe 189 feet long. The No. 5 nozzles were multiorifice nozzles having the same flow rate as single orifice nozzles with orifice diameter of 5/36 inches.

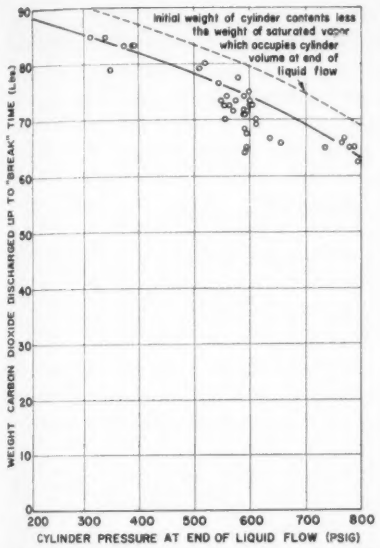

Initial weight of cylinder contents less the weight of saturated vapor which occupies cylinder volume at end of liquid flow
WEIGHT CARBON DIOXIDE DISCHARGED UP TO "BREAK" TIME (Lbs.)
CYLINDER PRESSURE AT END OF LIQUID FLOW (PSIG)

Figure 9. Cylinder pressure vs. the total weight of carbon dioxide discharge up to the time of the end of the liquid discharge from two 50 pound cylinders. The reason for the rather widely scattered points is not clear although there are possible explanations.

which there was no restricting orifice in the supply line.

Before these tests it was thought that the density of the CO_2 in the pipe line might be an important factor in extinguishment. It proved not to be so. However, having the data, it is interesting to note in Figure 7 the comparison between the density calculated from pressure measurements and that measured directly by the Beta gage. The close agreement shows that little heat is picked up by the CO_2 while flowing in the pipe.

Another question was what happens when the cylinder storage temperature is such that there is no liquid in the cylinder, that is, when the temperature is above the critical. Figure 8 illustrates the results of this research.

When it comes to designing a carbon dioxide extinguishing system, we wish to know in addition to the required rate-of-flow and horn velocity how

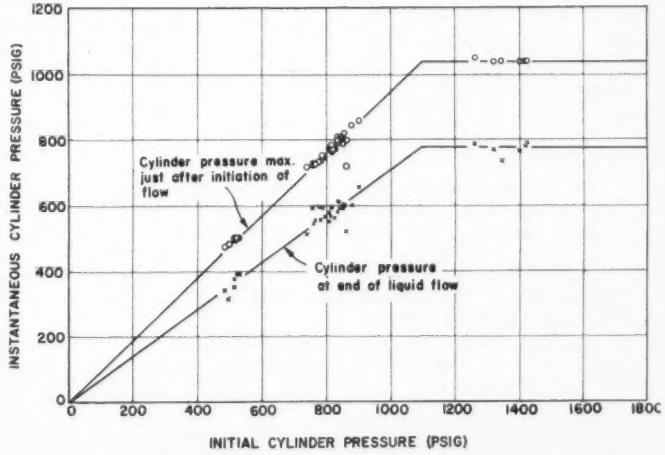

Cylinder pressure max. just after initiation of flow
Cylinder pressure at end of liquid flow
INSTANTANEOUS CYLINDER PRESSURE (PSIG)
INITIAL CYLINDER PRESSURE (PSIG)

Figure 10. Initial cylinder pressure vs. cylinder pressure at maximum and cylinder pressure at end of liquid flow. Because there is a small drop in cylinder pressure just at the beginning of discharge while the pipe line is filling, the maximum just after liquid flow starts averages 95 percent of the cylinder pressure before flow, up to the critical pressure of 1057 psig. The pressure at the end of liquid discharge averages 70 percent of the cylinder storage pressure up to the critical pressure and, at pressures above the critical, averages a constant 770 psig which is about 70 percent of the critical pressure.

much liquid carbon dioxide is available and the pressures at the beginning and end of liquid discharge. Figure 9 gives us this information. End of liquid discharge is shown as "Break" time in Figure 9. The pressure at the beginning and end of liquid discharge is shown on Figure 10.

Summary of Test Results

The rather limited objectives of the tests were accomplished. With a given nozzle design at a fixed height above the hazard, it was found that extinguishment depended upon only three factors:

1. The area covered per nozzle.
2. The weight-rate of carbon dioxide application.
3. The velocity of the carbon dioxide through the face of the nozzle horn.

The proportion of carbon dioxide in the liquid phase in the piping or the solid phase in the discharge were found not to affect the extinguishing ability. Hesson's methods of computation were adapted to permit design of a delivery system to meet the criteria for extinguishment. These methods were checked by tests. The method devised is sufficiently reliable to determine the effect of varying the size of nozzle orifices, the length and diameter of piping and of cylinder storage temperatures.

Further work needs to be done to determine the effect of nozzle elevation and nozzle design on the extinguishing criteria. These tests will be made shortly in connection with the reapproval examination of all carbon dioxide extinguishing systems by the Factory Mutual Laboratories and by Underwriters' Laboratories, Inc.

Extinguishing Agent Developments—

New Compressed Gas Extinguisher

By Fred S. Palmer

"Freon"' Products Division, E. I. duPont de Nemours & Company

Portable fire extinguishers for use on Class B and C hazards are currently of three principal types, those using a compressed gas, a dry chemical, or a vaporizing liquid. The development of fire-fighting equipment, practices, and techniques over the last several decades has found places where each of these types serves an important function.

One of the promising avenues of research into fire extinguishing agents was a broad investigation of the halogenated compounds conducted by the Purdue Research Foundation for the U. S. Army Corps of Engineers.* This investigation confirmed early indications that halogenated hydrocarbons containing bromine were especially effective agents for dealing with flammable liquid fires and, more specifically, that the following four compounds offered the most promise for further development:

Chemical Names	Chemical Formulae	Halon Designations†
bromotrifluoromethane	$CBrF_3$	1301
dibromodifluoromethane	CBr_2F_2	1202
bromochlorodifluoromethane	$CBrClF_2$	1211
dibromotetrafluoroethane	$CBrF_2.CBrF_2$	2402

*For background information see the October 1951 QUARTERLY and the October 1954 QUARTERLY or the reprint of this material published in NFPA Q48-8, "The Halogenated Extinguishing Agents." (Price: $1.25).

†Halon numbers are designed for convenient and quick reference to the numerous chemical compounds listed. The first digit of the number represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; the fifth digit, the number of iodine atoms. In this system terminal zero digits are not expressed.

The Purdue evaluations were based on explosion suppression tests conducted in the laboratory, rather than on actual fire extinguishment tests. While these tests were helpful in screening and rating the various agents tested, it was evident at that time that they did not provide necessarily a true measure of the relative extinguishing effectiveness of the various agents. Consequently, Ansul and duPont undertook a joint fire test program using a highly refined fixed system technique designed to reduce experimental errors as far as possible and to give an accurate picture of the relative effectiveness of a wide variety of agents. The results of this program showed that one agent, bromotrifluoromethane (Halon 1301), was the most effective of the agents evaluated. The relative effectiveness by weight of the halogenated agents tested in this program with comparative information on other common agents is shown in the following listing:

Chemical Names and Halon Numbers	Relative Effectiveness
bromotrifluoromethane (1301)	100
dibromodifluoromethane (1202)	67
dry chemical	66
dibromotetrafluoroethane (2402)	57
bromochlorodifluoromethane (1211)	46
chlorobromomethane (1011)	45
carbon tetrachloride (104)	34
carbon dioxide	33

Bromotrifluoromethane (referred to frequently by its Halon designation 1301) is a liquefied compressed gas as stored and handled. It has a boiling

Based on an address by the author presented at the 64th NFPA Annual Meeting held May 16–20, 1960 at Montreal, P. Q., Canada.

point of minus 72°F and a vapor pressure of about 200 pounds per square inch gage at room temperatures. Thus it falls somewhere between carbon dioxide and the vaporizing liquid agents (such as carbon tetrachloride) as far as these two physical properties are concerned, and it is more correctly described as a *liquefied compressed gas* than as a *vaporizing liquid* agent.

Toxicity Studies

While these evaluations of effectiveness were being conducted, detailed toxicity studies on these halogenated agents and other similar materials were being carried out by the Underwriters' Laboratories Inc., the United States Army, and the Kettering Laboratory of the University of Cincinnati. These studies showed that 1301 was considerably less toxic than the other halogenated agents, as well as being more effective in extinguishing fires. Both in its natural state and after the chemical changes brought about by exposure to heat, 1301 was also shown to be less toxic on a volume basis than the common vaporizing liquid agents by the margins indicated in Table I.

The approximate lethal concentration of 1301 vapor was found to be 800,000 parts per million in the natural state and about 14,000 parts per million after decomposition occasioned by exposure to temperatures of 1400–1500°F. Expressed another way, *natural* (undecomposed) 1301 vapor did not reach a lethal level for the test animals until its concentration was 80 per cent by volume. In its *decomposed* state, the lethal concentration of 1301 vapor was found to be 1.4 per cent, by volume, of the atmosphere under the test conditions cited. By comparison, the approximate lethal concentration of carbon tetrachloride was found to be 28,000 parts per million, or slightly less than three per cent, by volume, in its pure state, and only 300 parts per million, or three hundredths of one per cent, when decomposed by heat. Chlorobromomethane proved to be less toxic than carbon tetrachloride, having a lethal concentration of 65,000 parts per million in its undecomposed state and 4,000 parts per million, or 4 tenths of one per cent, when decomposed by heat.

On the basis of these tests, in its undecomposed state, 1301 is $\frac{800,000}{28,000}$ or approximately 29 times less toxic than carbon tetrachloride, and $\frac{800,000}{65,000}$ or about 12 times less toxic than chlorobromomethane. Similarly, when decomposed by heat, 1301 is about 47

Table I

Relative Toxicity of Agents

Based on Research by the Army Chemical Center

Agents and Halon Numbers	Approximate Lethal Concentration in ppm. Based on 15 minute exposure to vapors		Approximate Relative Toxicity (Volume Basis) Based on 15 minute exposure to vapors	
	Natural Vapor	Decomposed Vapor	Natural Vapor	Decomposed Vapor
bromotrifluoromethane (1301)	800,000	14,000*	1	1
chlorobromomethane (1011)	65,000	4,000	12	3½
carbon tetrachloride (104)	28,000	300	29	47

*Subsequent tests by Kettering Laboratory (unpublished data) with a commercial product of improved quality indicated that the lethal concentration of decomposed vapor is at least 20,000 ppm.

Table II

Relative Hazards in Use

Agents and Halon Numbers	Relative Toxicity (weight basis) Natural Vapor	Relative Toxicity (weight basis) Decomposed Vapor	Relative Efficiency	Relative Hazard Natural Vapor	Relative Hazard Decomposed Vapor
bromotrifluoromethane (1301)	1	1	X 1 =	1	1
chlorobromomethane (1011)	14	4	X 4 =	56	16
carbon tetrachloride (104)	28	45	X 5 =	140	225

times less toxic than carbon tetrachloride and 3½ times less toxic than chlorobromomethane. These comparisons relate to decomposition of a considerable portion of the extinguishing agent by exposure to temperatures of 1400-1500°F, a condition which is difficult to attain in many fire situations where there is sufficient ventilation so that relatively small quantities of the agent come into contact with the hottest areas of the fire.

The foregoing comparisons simply are measures of the relative toxicities of these agents. This, however, is only part of the picture. It does not provide a completely reliable measure of relative toxicities in fire situations because it does not take into account differences in the amounts of vapor produced by equal weights of the agents or, more importantly, the total amount of agent required to extinguish the fire.

A clearer understanding of the toxicity hazards arising from the use of these agents in comparable fire situations can be obtained from Table II.

The first two columns of Table II are a modification of data presented in Table I. In these two columns the relative toxicities are expressed on a *weight* basis rather than on a *volume* basis. The values shown in the third column of figures, under the heading of "Relative Efficiency," have been computed from information on the performance of existing commercial carbon tetrachloride and chlorobromomethane extinguishers and upon tests of 1301 extinguishers conducted under conditions similar to those used by Underwriters' Laboratories for classification purposes. Such tests indicate that one pound of bromotrifluoromethane has the fire extinguishing effect of about four pounds of chlorobromomethane or five pounds of carbon tetrachloride leading to the estimate that, on a weight basis, bromotrifluoromethane is four times as effective as chlorobromomethane and five times as effective as carbon tetrachloride.

Therefore, the actual relative hazard of the different agents under identical conditions of fire extinguishment is the product of the relative toxicity and the relative efficiency, as shown in columns 4 and 5, under the heading of "Relative Hazard." The figures in column 5 would indicate that bromotrifluoromethane is 1/225 as toxic as carbon tetrachloride and 1/16th as toxic as chlorobromomethane under actual fire extinguishment conditions.

What is the theoretical significance of these computations in fire-fighting situations? One pound of carbon tetrachloride allowed to completely vaporize in a closed room having a volume of 1,000 cubic feet would produce a natural vapor concentration of 2,700 parts per million. This concentration is about one-tenth of the lethal concentration of the natural vapors but nine times the lethal level shown in Table I for decom-

posed carbon tetrachloride. Equal fire fighting efficiency would theoretically be obtained from one-fifth of a pound of 1301 in a room of the same size. This amount of agent would result in a concentration of only 500 parts per million which is 1/28th of the lethal level for this agent in its decomposed state.

Present Usage of 1301

The high efficiency, low toxicity, the desirable chemical and physical properties of the agent, and its freedom from corrosive effects, has led to the adoption of 1301 by the major aircraft manufacturers for use as an aircraft engine fire extinguishing medium. Today nearly all American-made commercial aircraft use this agent for protection against in-flight engine fires.

The 1301 agent also has been chosen by the Corps of Engineers of the Department of the Army as the agent for use in their newest light-weight, portable fire extinguisher, containing two and three-quarters pounds of 1301, which was completed last year and procurement began at that time.

Extinguisher Design Characteristics

The effectiveness of a chemical extinguishing agent is only one vital part of an effective extinguisher. Regardless of the agent's effectiveness, it must be applied properly to the fire in order to have its maximum effect. The problem is not as simple as taking an extinguisher designed for carbon tetrachloride or carbon dioxide and replacing the agent with 1301. Particularly, the discharge

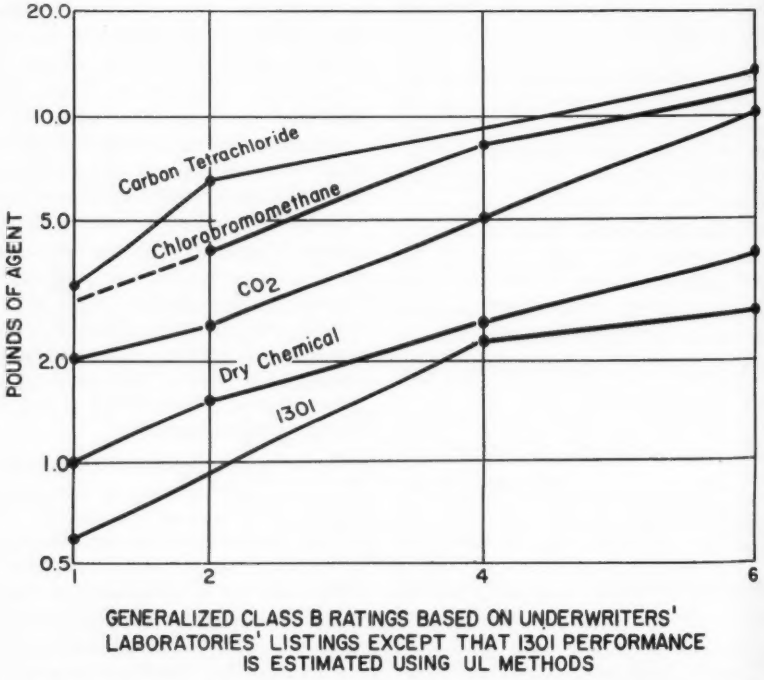


Figure 1. Probable performance of Halon 1301 compared to other commercially available extinguishing agents.

orifice and horn must be designed specifically for 1301, just as the nozzles for carbon tetrachloride and carbon dioxide extinguishers have been designed specifically for those agents.

Design studies of this type have led to a family of extinguishers which we trust will meet the fire-fighting performance required to attain Underwriters' Laboratories classifications ranging from 1–B:C to 6–B:C. Actual Underwriters' Laboratories testing is currently in progress. These units range in size from about one pound net weight to three pounds.

The probable performance of these new extinguishers, in relation to other types of commercially available units, is shown in Figure 1. The curves for all agents except 1301 are based on the listings published by Underwriters' Laboratories. In the case of 1301, the curve is based on tests conducted under conditions identical with those used by Underwriters' Laboratories.

Great care must be taken in interpreting these curves because they do not represent necessarily the maximum performance that can be attained. For example, four-pound (one quart agent capacity) chlorobromoethane extinguishers are listed as 1–B:C even though some of this size have ratings of 2–B:C. Obviously, 1–B:C performance can be attained with less than the best one-quart extinguisher and the dotted line would represent more truly the performance of this agent.

Also, one manufacturer has a 10-pound carbon dioxide extinguisher listed with a rating of 8–B:C, while all 6–B:C extinguishers of this type also contain at least ten pounds of agent.

In spite of such discrepancies, this graph confirms that 1301 is at least equivalent in effectiveness to dry chemical as reported in "The Chemical Aspects of Fire Extinguishment" by Arthur B. Guise in the April 1960 NFPA QUARTERLY. It is interesting to note also that the current information obtained from extinguisher design studies with 1301 indicates that the performance of this agent, when used in properly designed units, may be very close to the effectiveness indicated by the data given herein.

Extinguishing Agent Developments —

Trimethoxyboroxine for Magnesium Fires

By Raymond R. Neill
Engineering Research Branch
U. S. Naval Research Laboratory

The problem of extinguishment of fire occurring in the magnesium components of aircraft involved in crash situations has increased with the expanding use of magnesium alloys in airframes. These magnesium-alloy fires occur most frequently in crashes after fuel fires ignited thin sections of the alloy. In addition, wheel castings have ignited from overheating caused by abrasive friction on runways because of blown tires, brake seizures, or other landing gear failures.

Fire Properties of Magnesium

The ignition temperature of magnesium is very close to its melting point of 651°C (1,204°F), and magnesium alloys used in aircraft ignite at somewhat lower temperatures. Tests made at the Naval Research Laboratory on the heating and ignition of slabs of varying thicknesses of an alloy suspended over a gasoline fire show that the larger ones take a longer time interval to ignite than thinner slabs. Thick or bulky castings, such as landing wheels or support members, are difficult to ignite because the high heat conductivity of the metal and the resultant rapid transfer of heat throughout such castings prevents localized heating to the ignition point. Once ignited, however, thick castings are difficult to extinguish. Small parts and thin sheets ignite more rapidly, and, because of the greater surface exposed, burn more rapidly.

Based on an address by the author at the 64th NFPA Annual Meeting held May 16–20, 1960 in Montreal, P. Q., Canada.

Burning magnesium reacts with most commonly used extinguishing agents. Because of the reactivity of the burning metal, such agents as carbon dioxide and the halogenated hydrocarbons are not satisfactory. Magnesium combines so readily with oxygen that under some conditions water applied to extinguish magnesium fires may be decomposed into its constituent elements, oxygen and hydrogen. The oxygen combines with the magnesium and the hydrogen released adds to the intensity of the fire.

Several investigators[1,2,3] studying extinguishing agents for magnesium fires have published excellent bibliographies on the subject of devices and materials for magnesium fire fighting. At our laboratory, a preliminary survey of the available commercial materials pointed out the need for a better extinguishing agent for application in aircraft incidents with the following characteristics:

1. It should be a liquid capable of "throw" into the inaccessible areas using normal liquid dispensing methods.

2. It must be nontoxic.

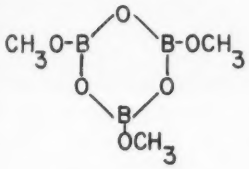
3. It must not be flammable to the extent of generating a secondary fire so large that other agents are required to combat it.

4. It should exert a fire extinguishing or controlling action on the magnesium which will not be cancelled out by the successive application of water and/or foam as cooling and blanketing agents.

5. It should be noncorrosive and stable during storage.

Selection of Agent

One of the compounds available from the high-energy fuel program was an anhydrous liquid, called trimethoxyboroxine, or "TMB," which held considerable promise as a new magnesium fire extinguishing agent. TMB is a clear, colorless liquid compound of boron having a molecular weight of 173.6 and is represented by the cyclic structural formula:



The compound is formed by reacting methyl borate with boric oxide (B_2O_3) in an autoclave at 120°C and under a pressure of 60 psi. The preparation of TMB is expressed by the following reaction:

$$(CH_3O)_3B + B_2O_3 \rightarrow (CH_3O)_3B.B_2O_3$$

Physical Properties

The following table depicts some of the physical properties of TMB which are of interest when one considers its use as a fire extinguishing agent.

Typical Physical Properties of TMB

Specific Gravity 20°/20°	1.2125
Surface Tension	24.4 dynes/cm (25°C)
Viscosity	13.18 centipoises (25°C)
Pour Point	−30°C (−22°F)
Turbidity (Light transmission)	98%
Flash Point	15°C (59°F)

The fact that TMB is flammable results in a secondary fire from TMB when it is applied as an extinguishing agent but this secondary fire is of only momentary duration and can be tolerated in the fire extinguishment process.

TMB weighs approximately 10 pounds per gallon. With its low surface tension the liquid readily penetrates cracks and crevices in any burning mass of magnesium. The factors of viscosity and pour point are important considerations in its use from an extinguisher. The clarity of the liquid indicates its purity, while the concentration of boric oxide is kept as high as possible to increase its extinguishing effectiveness.

Extinguishing Mechanism

It is of fundamental importance to understand the extinguishing mechanism by which TMB operates to control a magnesium fire. At high temperatures liquid TMB decomposes to form boric oxide, a viscous, glassy substance, as represented in the formula:

$$(CH_3O)_3B.B_2O_3 \xrightarrow{\text{heat}} B(OCH_3) + B_2O_3$$

The methyl borate, in the presence of oxygen, burns to yield additional boric oxide according to the formula:

$$2\ B(OCH_3)_3 + 9O_2 \xrightarrow{\text{heat}} 6\ CO_2 + 9H_2O + B_2O_3$$

Experimental evidence has proven that TMB, when applied to burning magnesium, forms a glassy coating of boron oxide to exclude oxygen from the surface preventing further combustion.

How Magnesium Burns

Another fundamental fact uncovered by our research, was that magnesium burns in two ways. *First*, the metal burns as a result of vaporization. This is evidenced by the brilliant white flame and by the cloud of white magnesium oxide smoke given off during the burning process. This type of combustion takes place at the surface where the oxygen supply is plentiful, and results in a flame temperature of over 5,000°F. TMB was found to be effective in knocking out this brilliant fire.

Figure 1. TMB extinguishers in Navy crash truck.

The *second* type of burning takes place at a much reduced rate and without external visual evidence of flame or smoke. It is characterized by a dull red color at the surface of the metal which is visible when the mass is not hidden under too thick a coating of oxide. These mechanisms can be compared to the appearance of wood burning in early stages with gases being evolved, and the later stages when the wood oxidizes slowly as solid charcoal embers. Both types of burning will completely convert the metal to the oxide, but at somewhat different rates of heat output.

An extremely important discovery was made at this point in the research program. It was found that water could be applied at this later "red glowing" burning stage without causing any vigorous reaction, such as occurs if water is applied to magnesium burning in the primary or "white fire" stage. This offered promise of a new technique in extinguishing magnesium fires using a combination of TMB agent and water.

Current U. S. Navy Usage

Extinguishers employing TMB are now being carried on U. S. Navy aircraft fire fighting vehicles under directives issued by the Bureau of Naval Weapons. The amount of agent supplied is purposely small, each vehicle having two 2½-gallon stored pressure type extinguishers of the type shown in Figure 1. This limited quantity restricts the use of TMB to short applications on the primary or "white fire" burning stage of magnesium. The amount of such an agent that would be required to cool a burning mass of magnesium below its solidification temperature would, on the other hand, be considerable. Water is available on the vehicles in sufficient quantities for this purpose. The technique used is thus to first inert the magnesium "white fire" with TMB, following this up by cooling with available water. In this technique of "combined agent" application, TMB is applied sporadically to quench the "white fire" and provide a boric oxide coating. Figure 2 demonstrates this application. Water is then sprayed over the mass for cooling. Intermittent application of TMB and water as white hot spots develop will produce final extinguishment. Foam from these vehicles can be used to cool adjacent metal surfaces, but care must be taken not to pile foam on the burning magnesium parts because it interferes with the application of TMB.

Field Experience with TMB

The most successful uses to date have been on special magnesium fire incidents. One such incident at a Naval Air activity involved an aircraft power plant fuel flooding condition and backfire which caused a fire in the carburetor intake and ducting, both made of magnesium. This fire was inside the engine cowling and before the latter could be removed, a 3-inch diameter hole had burned through the cowling bottom. TMB was applied through this aperture and successfully extinguished the fire

Figure 2. Example of application of TMB to the "white fire" of burning magnesium.

with several short bursts of the liquid. Water was then used to cool the components using a handline.

TMB has also been used on wheel fires in conjunction with water spray judiciously applied for cooling and final extinguishment. In a recent incident involving an F8U-1 at Naples, Italy, this technique was applied in extinguishing a wheel fire resulting from an excessively high speed landing.

Limitations of TMB

The worst types of situations involving magnesium fires are the result of impact where parts of the aircraft are scattered, some even being half buried in the dirt or sand. Here, the use of a specialized agent such as TMB is not prescribed too strongly. Common sense dictates that the use of water, applied from a distance, and careful overhaul of the mass with a pike pole or some such implement is most effective. Several incidents involving helicopters, which are almost completely fabricated of magnesium sheet, have been particularly vicious and such fires are clearly beyond the capability of the agent in the quantities supplied.

Summary

TMB is not advocated as a panacea to the magnesium fire problem in aircraft crash incidents. It was introduced as a specialized tool to provide the best material presently available for practical field usage. It will not extinguish all magnesium fires in all situations, but used with regard to its inherent favorable features, will do a creditable job of assisting magnesium fire extinguishment. It is a liquid capable of being directed accurately onto the magnesium fire, possesses the capability of quenching the existing white fire, and reduces the hazard of using water spray application for final extinguishment.[4]

References

(1) Kling, A. L., et al., "Protection of Aircraft Against Magnesium Fires," Factory Mutual Research Corp., AAF Tech. Report 5526, Aug. 1946.

(2) McCutchan, R. T., "Investigation of Magnesium Fire-Extinguishing Agents," Wright Air Development Center Tech. Rpt. 54-5, Jan. 1954.

(3) Greenstein, L. M. and Richman, S. I., "A Study of Magnesium Fire Extinguishing Agents," WADC Tech. Rpt. 55-170, May 1955.

(4) Tuve, R. L., et al., "The Use of Trimethoxyboroxine for the Extinguishment of Metal Fires," NRL Report 4933, 10 July 1957.

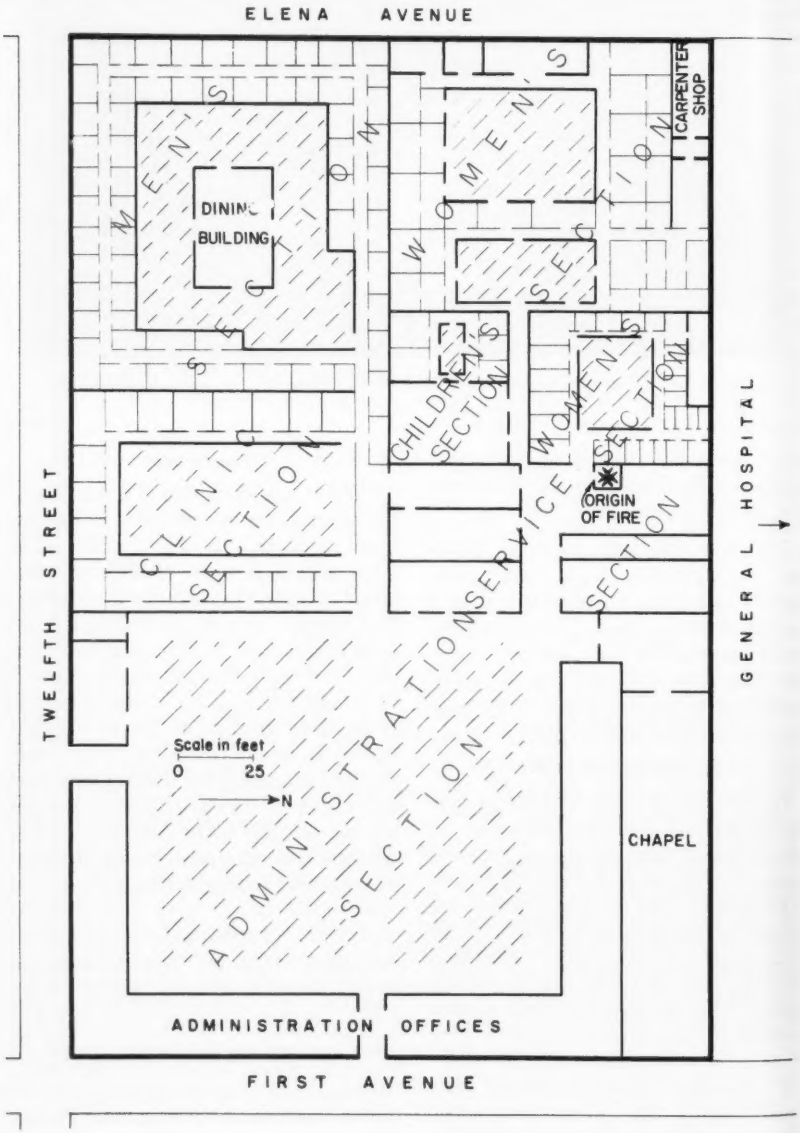


Figure 1. The Neuro-Psychiatric Hospital in Guatemala City was said to be typical of Latin-American construction — consisting of squares of rooms and offices opening on inside patios. The open patios are designated by diagonal broken lines.

Guatemala Mental Hospital Disaster

On July 14, 1960, an estimated 170 persons, including 139 female patients, 30 male patients and one employee, lost their lives in a fire that destroyed two thirds of the Neuro-Psychiatric Hospital in Guatemala City, Guatemala. Eighty persons were injured. The exact number which perished could not be established since about 200 of the 1,353 patients in the overcrowded hospital took advantage of the confusion to lose themselves in the city. The employee who died was trapped while trying to rescue patients.

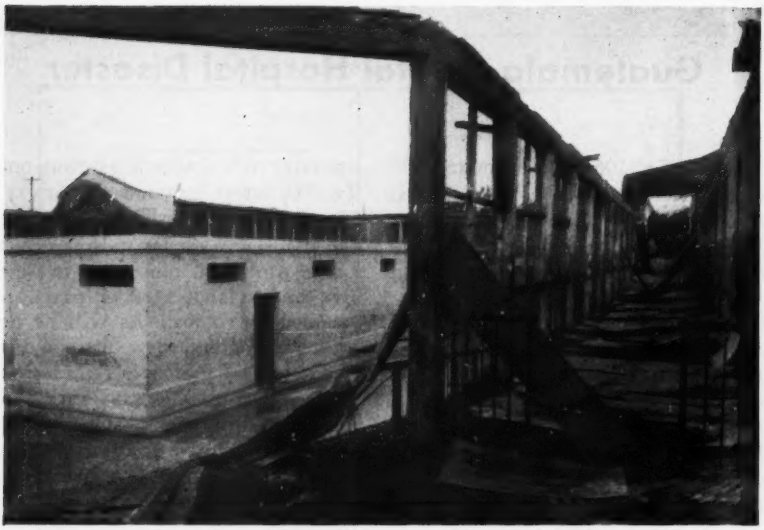
The Hospital Building

The Neuro-Psychiatric Hospital occupied an area 325 ft. long by 162 ft. wide that was surrounded by a 12-ft. to 14-ft.-high masonry wall. There were no windows in the wall. The only openings were a vehicle gateway on the Twelfth Street side and a doorway on First Avenue. (See Figure 1.) Within the walled area the layout was typically Latin American consisting of several *open patios* (landscaped or paved) surrounded by rooms. As will be noted from the diagram, the rooms and dormitories in the patient sections usually opened into passageways rather than directly to the patios. One such passageway is shown at the right in the photograph on page 184. Heavy wire mesh separated this passageway from the patio.

The patios did not act as fire divisions since the construction surrounding the patios adjoined and comprised one large fire area due to concealed spaces between the sloping sheet metal roof and the wooden ceilings of rooms and passage-

Mario Tercero

The undivided concealed spaces between the metal roof and wooden ceiling allowed the fire to spread to all Sections of the hospital. Flames also spread through corridors on burning down through the wooden ceilings.



This photo was taken from the northeast corner of the Men's Section looking toward the dining building in the patio. The passageway at right was part of the only route out for occupants of this Section.

ways. Walls and partitions were adobe or concrete, and wood supported the metal roofs and wooden ceilings.

The only way out of the Men's and Clinic Sections was through the east-west passageway that discharged into the Administration Section patio. Another east-west passageway through the Service Section to the Administration Section patio was the only route out of the Women's and Children's Section.

The basic fire protection for a combustible mental hospital — automatic sprinklers — was not provided nor were standpipe and hose systems nor even portable fire extinguishers. The nearest fire hydrant was two blocks away.

A further indication of the lack of fire safety at this hospital was the wiring method which consisted of open wiring attached to walls.

The Fire

On the evening of July 14, two elderly women employees were in a small ironing room in the Service Section (see Figure 1) ironing clothes. The room contained a large quantity of cotton clothing, ironing boards, charcoal braziers for heating the irons, gasoline for igniting the braziers, an electric iron and a small altar.

At about 9:00 P.M. the electric light in the room went out. Candles were lit on the altar so the women could see to finish their work, and at 9:30 P.M. they left for the night locking the room behind them. They forgot to disconnect the electric iron and may have left the candles lit. Whether a candle or the iron was responsible for the small fire that was discovered in the ironing room by an employee at 11:00 P.M. could not be determined. In either case, the cause of the fire was not so important as was the fact that when the fire was discovered the fire department was not called. Instead, a few women employees fought it alone and, believing they had put it out, went back to bed. On

being awakened at 1:00 A.M., employees again found the ironing room on fire; but this time the flames were obviously more than they could cope with so the fire department was called.

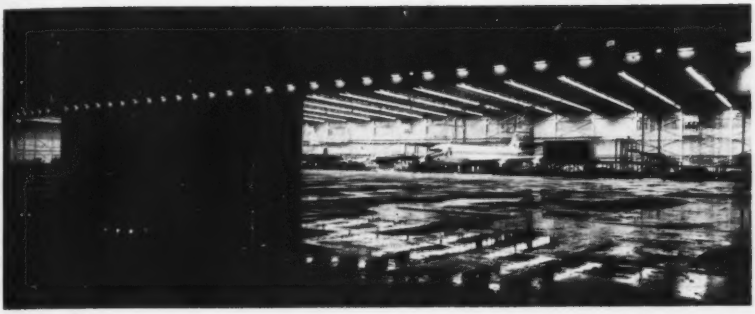
The first company of volunteer firemen is said to have arrived five minutes after the alarm was given. Fire had by then burned through the wooden ceiling and was burning above the Service Section in the concealed space formed by the metal roof and the wood ceilings. It was also spreading through this undivided concealed space in easterly and southeasterly directions to the patients' sections.

The immediate problem confronting the firemen and employees was rescue of patients. Assisted by citizens attracted by the excitement, they were able to guide to safety most of the patients who had occupied the westerly Women's Section, the Children's and Clinic Sections and the westerly end of the Men's Section. This evacuation was through the only routes available, the two long narrow east-west passageways that discharged into the Administration Section patio. These and some of the feeder passageways were usable only for a relatively short time, however, due to smoke conditions and the early collapse of burning parts of the fire-weakened ceiling at several locations. Approximately 400 patients were still in the Men's Section and the easterly Women's Section. Before flames completely enveloped the hospital 164 women were taken out from the Women's Section through a hole made in the wall on the General Hospital side and about 100 women were rescued through barred windows that overlooked the wall on Elena Avenue. An unreported number of male patients was rescued through holes made in the Elena Avenue and Twelfth Street walls surrounding the Men's Section. Most of the victims died of asphyxiation in their rooms.

When this photo was taken the fire had burned down through the wooden ceilings from the concealed roof space through which it originally spread.

Considering the inadequacy of the exits, the lack of sprinkler protection, the mental condition of the patients and the delayed discovery of the fire, it is remarkable that so many survived.

Fire fighting was as effective as could be expected with the facilities available. The area in which the hospital was located was protected by a volunteer fire department. Forty volunteer firemen eventually responded with their three pumpers, all of which were required to relay water from the nearest hydrant which was two blocks from the hospital entrance. Water gotten to the scene through the relay was used primarily to keep the fire from spreading to buildings of the General Hospital. The volunteer fire fighters were later assisted by firemen and two tank trucks from another fire department. By 4:00 A.M. the fire had died down sufficiently so that it could be controlled and by 8:00 A.M. it was out.



TCA Hangar Foam-Water Deluge Sprinklers

By E. W. Sellors
Chief Architect, Trans-Canada Air Lines

Trans-Canada Air Lines has just recently put into use a new Maintenance and Overhaul Base at Montreal International Airport. Nearing completion, this facility will be home base for 10 Douglas DC-8 jetliners and 23 Vickers Vanguards. Overhaul and maintenance for turbine-powered Viscounts will continue at the Winnipeg base.

TCA's big Montreal project has evoked widespread interest, both for the bold functional architectural and engineering features of the buildings themselves, and for the modern servicing equipment that will keep the jets in top condition. On the 84-acre site, buildings totaling over 18 acres of floor space include the two huge hangars, headquarters offices, storage, unit overhaul shops, and training facilities.

Of especial interest to NFPA members is the fire protection, which became a prime consideration at the very outset of the project — in particular the foam-water deluge sprinkler system in the hangars, which was considered essential to guard both the buildings and equipment and the multimillion dollar aircraft. So far as is known, this is the third such installation in the world in a commercial airlines hangar (one being in Vancouver, B. C., the other in Stockholm) and the largest, covering some six acres of floor space.

Trans-Canada Airlines Overhaul and Maintenance Base at Montreal International Airport.

Base Facilities

The design of the new base evolved around two separate (adjoining) hangar buildings, the heart of the service facilities.

The OVERHAUL HANGAR, the larger of the two, can house five DC-8's in line. The hangar had to be completely enclosed to permit operation during Montreal's coldest weather, when temperatures sometimes drop to as low as 30 degrees below zero.

Believed to be the world's largest single-cantilever structure, this hangar has a roof 837 ft. long and 175 ft. wide, suspended 63 ft. above the floor from exterior cantilever trusses. Inside, purlins on seven ft. open trusses support the metal deck roof, which has two inches of fiberglass insulation and is covered with tar and gravel. Full-height doors, that slide on floor tracks, are along one lengthwise wall. Building walls are concrete block.

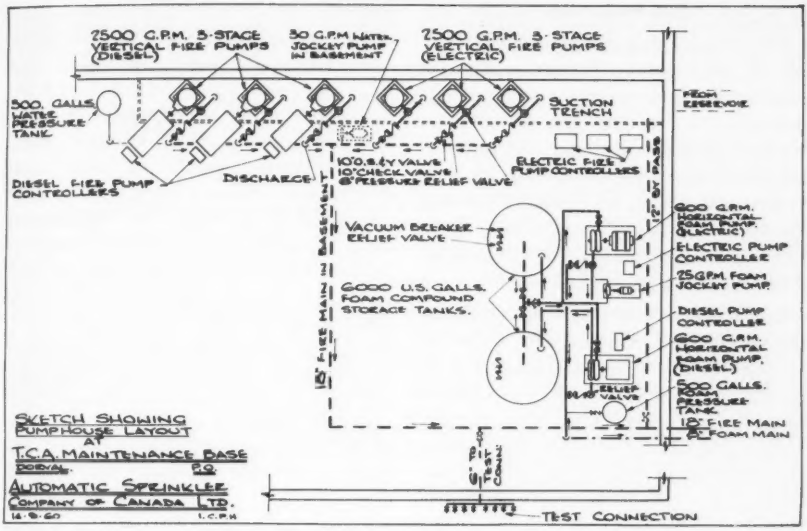
Each 175-ft. single-cantilever truss is pivoted on steel columns at the rear wall and has in addition two pin connections along its length, at 55 feet and 143 feet. Under varying conditions of wind, snow load or temperature, the extreme edge of the cantilever structure, over the doors, can move in a range of 28 inches in an up-down travel — 14 inches on each side of the normal position; other flexing actions, not so easily calculated, can occur at each pin connection. (This posed a problem in the fire protection piping design, referred to on page 191.)

The smaller LINE MAINTENANCE HANGAR, which adjoins the end wall of the Overhaul Hangar, is a 235 ft. by 487 ft. double-cantilever building. A 40-ft. wide central structure of reinforced concrete running lengthwise of the building, with 40 ft. clearance at its lowest point, rests on four 40-ft. wide pylons. The exterior double-cantilever trusses slope upward from this concrete center structure to a height of 58 feet over the door rails along each side of the building. Inside the hangar, 36-inch girders are supported from the exterior trusses; on these, 10-inch purlins support metal roof decking, with roofing similar to the Overhaul Hangar. The end wall adjoining the Overhaul Hangar is of concrete block, and exterior walls are brick and aluminum siding.

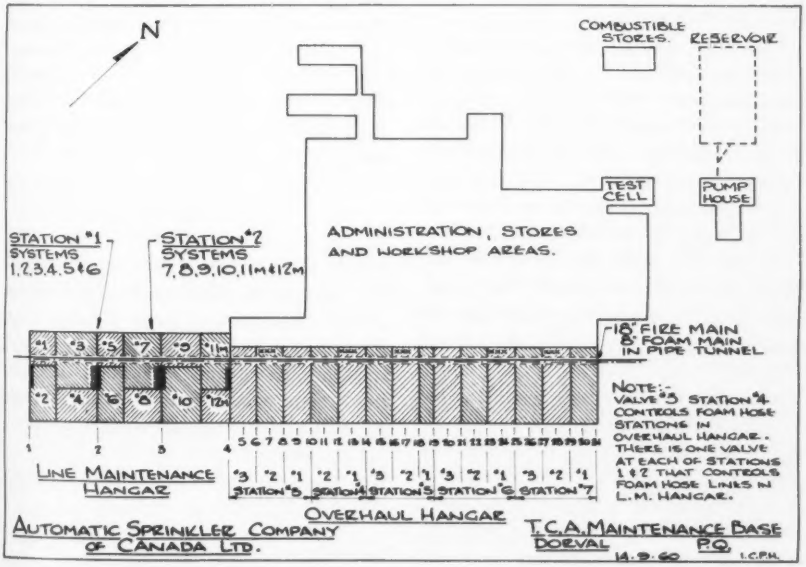
Abutting the back end of the Overhaul Hangar is the Overhaul Hangar Annex and an adjoining structure housing the stores area, unit overhaul shops and power plant overhaul shops, totaling 281,000 square feet. A small reinforced concrete building houses turbine engine test cells where the jet power plants are tested after overhaul.

Connected to the main area and to each other by enclosed corridors are two air-conditioned buildings which house offices, an electronic data processing center, medical center, cafeteria, flight simulators and training areas. These structures, three stories high and covering a ground area of 125,000 square feet, are of metal and glass curtain-wall construction with steel frame and concrete slab roof.

A separate building houses the heating plant, air-conditioning units, air compressors, main 12,000 volt electrical substation and emergency power plant, as well as the fire pumps and the foam liquid pump and storage tanks. This utilities building is connected to the main building complex by a concrete pipe tunnel approximately 350 feet long. All fuel storage is above ground in separate storage tanks. A separate combustible stores building is provided and is set apart from the main building complex.


2500 G.P.M. 3-STAGE VERTICAL FIRE PUMPS (DIESEL)
30 G.P.M. Water JOCKEY PUMP IN BASEMENT
2500 G.P.M. 3-STAGE VERTICAL FIRE PUMPS (ELECTRIC)
500 GALLS. WATER PRESSURE TANK
SUCTION TRENCH
FROM RESERVOIR
DISCHARGE
DIESEL FIRE PUMP CONTROLLERS
10"O.S.&Y. VALVE
10"CHECK VALVE
8"PRESSURE RELIEF VALVE
ELECTRIC FIRE PUMP CONTROLLERS
VACUUM BREAKER RELIEF VALVE
600 G.P.M. HORIZONTAL FOAM PUMP (ELECTRIC)
ELECTRIC PUMP CONTROLLER
25 G.P.M. FOAM JOCKEY PUMP
6000 U.S. GALLS. FOAM COMPOUND STORAGE TANKS.
DIESEL PUMP CONTROLLER
600 G.P.M. HORIZONTAL FOAM PUMP (DIESEL)
RELIEF VALVE
500 GALLS. FOAM PRESSURE TANK.
12" FIRE MAIN & FOAM MAIN
10" FIRE MAIN
SKETCH SHOWING PUMP HOUSE LAYOUT AT T.C.A. MAINTENANCE BASE DOEVAL P.Q.
AUTOMATIC SPRINKLER COMPANY OF CANADA LTD.
14-9-60
I.C.P.H.
TEST CONNECTION

Schematic layout of the fire protection equipment in the Boiler House Building.


N
COMBUSTIBLE STORES.
RESERVOIR
TEST CELL
PUMP HOUSE
STATION #1 SYSTEMS 1,2,3,4,5 & 6
STATION #2 SYSTEMS 7,8,9,10,11m & 12m
ADMINISTRATION, STORES AND WORKSHOP AREAS.
18" FIRE MAIN & FOAM MAIN IN PIPE TUNNEL
NOTE:- VALVE #3 STATION #4 CONTROLS FOAM HOSE STATIONS IN OVERHAUL HANGAR. THERE IS ONE VALVE AT EACH OF STATIONS 1 & 2 THAT CONTROLS FOAM HOSE LINES IN L.M. HANGAR.
LINE MAINTENANCE HANGAR
OVERHAUL HANGAR
STATION #5
STATION #4
STATION #3
STATION #6
STATION #7
AUTOMATIC SPRINKLER COMPANY OF CANADA LTD.
T.C.A. MAINTENANCE BASE DOEVAL P.Q.
14-9-60
I.C.P.H.

Plan view of the TCA Base showing the area and locations of 26 Foam-Water Deluge Sprinkler Systems in the Hangar Buildings.

Fire Protection

This project had its inception in the fall of 1957 when Trans-Canada Air Lines had completed plans for the conversion of its entire fleet to turbine-powered aircraft. Putting into practice one of the precepts stressed by fire protection engineers, TCA architects and engineers and their consulting engineering firm planned their fire protection as an integral part of the project.

Standard sprinkler systems were chosen for the offices, stores and shop areas, to be installed in strict accordance with the NFPA Standard for the Installation of Sprinkler Systems (No. 13). In the turbine engine test cells, standard sprinkler protection was provided for the reinforced concrete building structure, with water deluge systems in the cells themselves, and a manually operated high-pressure CO_2 system surrounding the power-plant cradles.

Hangar Fire Protection

Protection for the hangars presented a special problem. It was recognized that standard water deluge systems could control major structural damage to the building. But these were no ordinary sized hangars, and the considerations that had to be weighed included both the buildings and equipment and the multimillion dollar aircraft that would be housed. Not only were the aircraft worth up to $6,000,000 apiece, but loss of equipment could seriously disrupt TCA's operating schedules, causing much passenger inconvenience and affecting the airline's revenues. The possibility that up to 18,000 Imperial gallons (21,600 U. S. gallons) of JP-4 jet fuel could be aboard a hangared aircraft added urgency to the necessity of providing fire protection over and above the standard water deluge systems customarily used in hangars.

Decision to Use Foam-Water Sprinklers

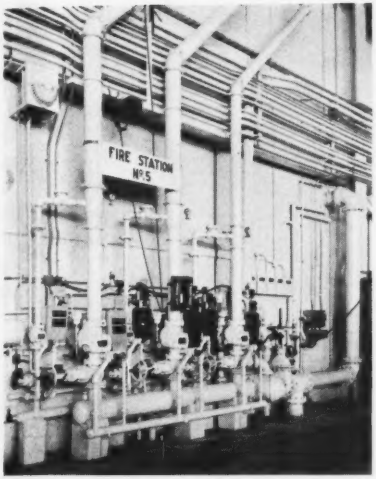
The use of foam-water deluge sprinkler systems for flammable liquid risks had been increasing in U. S. and Canada in 1957, and this type of system had been in service at U. S. military bases. The NFPA had published information on this new fire protection method since its initial development; an installation in a large USAF hangar had been reported in an article in the January 1955 QUARTERLY. A contract had recently been let for installation of this protection in a commercial airline hangar at Vancouver. This previous acceptance of foam-water deluge systems for aircraft hangar protection, and the fact that the NFPA had in May of 1957 approved standards covering this type of installation (Chapter 16 of the NFPA Standard on Aircraft Hangars, No. 409) all helped to guide TCA in its decision to specify foam sprinklers.

At the time TCA was making its preliminary decision, the Royal Canadian Air Force announced it had standardized on foam-water sprinkler protection for new hangar buildings, and shortly afterward the RCAF specified this type of protection for three new hangars which are now under construction.

The basic motive for TCA's ordering the foam-water deluge sprinkler system was its ability to protect aircraft in the hangars. It was felt that the smothering action of foam discharged from above and flowing over aircraft and floor would blanket even a major fuel spill fire to prevent complete aircraft loss. The additional probability that a spill could be covered with foam even before ignition was another factor in the decision to specify a foam deluge sprinkler system.

System Layout and Design

In the two hangars, the foam-water deluge protection is designed in 26 sys-



Typical Foam Deluge Valve Station arrangement showing the larger 6 in. Suprotex-Deluge Valves in the foreground and the smaller 2½ in. Companion Deluge Valves in the rear.

tems, 14 in the single-cantilever Overhaul Hangar and 12 in the double-cantilever Line Maintenance Hangar, using a total of twenty-six 6-inch water-deluge valves, with twenty-six 2½-inch companion deluge valves controlling the foam liquid lines. The foam-water sprinklers used, a total of 3080, are "Automatic" Sprinkler Type SD-2½PA. These are listed by the Underwriters' Laboratories, Inc. and the Underwriters' Laboratories of Canada both to distribute air foam when foam liquid is introduced into the water supply and to distribute water over the same area in the absence of foam liquid.

The system valves are grouped in seven valve stations: in the Overhaul Hangar, four 3-valve headers and one 2-valve header; in the Line Maintenance Hangar, two 6-valve headers. Paralleling each water-valve header is a valve header supplying foam liquid to the companion deluge valves.

Designed coverage density is based on a calculated discharge of 0.17 gpm of foam-water solution or plain water per square foot of floor area. In accordance with NFPA No. 409, all system piping is sized by hydraulic calculations for uniform discharge. System piping above the water deluge valve is galvanized.

To meet the engineering problem of the flexing of the cantilever structure, the sprinkler contractor provided against undue stresses on the pipe and the pipe hangars by using victaulic couplings on all feed mains; these couplings were placed at 10-ft. intervals to gain the extra bending required, and special provisions had to be made to anchor the extremely flexible victaulic-coupled pipe to prevent its movement under the pressure-surge effect of the fast opening of any 6-inch deluge valve under a high initial pressure.

Water Supply

A 1,000,000 U. S. gallon two-compartment underground reservoir supplies water for fire protection for the entire project. Six deep-well 2500 gpm vertical turbine fire pumps are located over a 17-ft. deep suction trench in the Pump House, fed from the reservoir through two 24-inch underground pipes with individual sluice gate valves.

Of these six 250-hp pumps, three are electrically driven units and comprise the primary pumping equipment; the three standby units are diesel powered. An 18-inch cement-lined cast iron underground water main from the pump header serves as supply to the hangar systems and to the hydrant loop and the sprinkler systems in office and shop areas. This underground line is kept pressurized by a 500-gpm electric-driven jockey pump, with a 500-gallon air cushion tank.

Approved fire pump controllers receive primary actuation from the circuit triggered by the weight switch when

Canada Wide Photo

The discharge of foam from overhead sprinklers obscures this photograph but illustrates the density of the foam coverage about 60 seconds after one system was operated.

any water deluge valve operates. This starts the first fire pump motor immediately, and the remaining units start sequentially at 5-second intervals. A secondary method of operation for the primary pumps is through pressure switches, when underground main pressure drops from the opening of a valve.

Should a power failure occur, the diesel units come on at electric power interruption and remain in operation until power is resumed. The diesel engine controllers also have pressure switch actuation should the electric units be unable to maintain satisfactory pressure for any reason.

This duplication of pumping capacity with both diesel and electric units was decided upon as being preferable to a single standby diesel electric generator capable of operating 850 hp of fire and foam-liquid pumps.

Foam Liquid Supply

Foam liquid is stored in the Pump House in two 6000 U. S. gallon steel storage tanks. The 6 per cent liquid, to JAN-C-266 and JFMC-260.00 Specifications, is the same standard as used by the Royal Canadian Air Force and all Canadian Government Departments, including the Department of Transport which operates the crash trucks and other fire protection services at Montreal International Airport.

The tanks are kept full, with a checked-off breather to break vacuum during draw-down, and provisions are made to keep air flow to a minimum.

Two 600 gpm (U. S.) centrifugal foam liquid pumps are provided, the primary unit powered by a 100-hp electric motor and actuated both from the weight switch on any water deluge valve and from a pressure switch on the 8-inch foam liquid supply line (supervised by a 25-gpm jockey pump and pressure tank). The standby unit, of same capacity, is diesel driven and, as with the water pumps, is designed to begin operation whenever electric power fails,

so as to be running should an emergency develop.

Underground Supply Mains

The 18-inch water main and the 8-inch foam liquid main are carried through the length of both hangars under the floor in a covered concrete pipe tunnel approximately 1400 feet long, back-filled with sand; this is to guard against any possibility of water reaching the cantilever structure footings should a rupture ever occur.

From these two mains, branch runs feed the seven water and seven foam liquid headers. Removable-basket strainers are provided for each header. In addition to the OS&Y control valves under each deluge valve, each header has a main control valve. These control valves are supervised by means of monitor switches.

Foam Solution Proportioning

To form the foam solution (94 per cent water, 6 per cent foam liquid) used in the systems, the foam liquid is injected into the system riser at a tee above the water deluge valve. The proportion is regulated by means of an orifice drilled in a stainless steel plate in the foam liquid piping near the injection point. The diameter of this proportioning orifice is calculated to pass the required volume of foam liquid at the pressure *differential* existing between the water pressure in the riser and the higher pressure in the foam liquid line.

The engineering considerations in the foam liquid proportioning are rather complex. The proportioning must take into account the viscosity and specific gravity of the foam liquid in relation to the water. An important factor in an installation of this size is the variation in pressure conditions that will exist between single system operation and the operation of several systems simultaneously. In the selection of the discharge-characteristic curves for the fire pumps and the foam liquid pumps, this had to be borne in mind. In sizing the orifices, allowance had to be made for this difference in operating pressures, taking care that in the two extremes (with a single system operating or with maximum expected demand) the proportioning will be within the allowable limits of the 6 per cent design point.

System Operation

Every step of the system operation is completely automatic.

The heat detection equipment which actuates the systems is of the pneumatic rate-of-rise type, with heat actuated devices located at the roof at prescribed spacing. An abnormal rise in temperature expands the air in the heat actuated devices in the affected area, and the expanding air pushes back through the air tubing to operate a release that opens the water deluge valve. Care was taken to select suitable compensating-vent ratings and release settings for the temperature conditions in the hangar.

The heat detection equipment is pneumatically supervised, with trouble lights at each water deluge valve and a remote indicator to signal any accidental damage.

Each water deluge valve is equipped with a weight switch and with a hydropneumatic control. Operation of the deluge valve admits water into the system riser and simultaneously, by means of the weight switch, a fire alarm is sounded, the foam liquid and fire pumps start, and the companion deluge valve (solenoid equipped) opens. As a secondary, nonelectrical method, the hydropneumatic control also operates the companion deluge valve.

When the companion deluge valve trips, foam liquid (which has been pressurized in the supply line right up to the companion valve) then flows

through the orifice into the system riser. The resulting *foam solution* is carried through the piping to the foam sprinklers; here, air is aspirated through intake ports in the base of the sprinkler to form expanded foam. Further aeration and expansion takes place while the discharge falls to the floor or intervening surfaces, and a foam blanket builds up, with proper consistency to flow along the floor.

Auxiliary Protection

To provide for localized extinguishing of small fires, or for spot-assistance to the foam-water sprinklers, 23 foam hose stations are located along the walls of the two hangars. Foam solution is supplied to these 23 stations from three deluge headers in a manner identical with that for the foam systems, but the water-deluge valve is actuated by hand operation of a pneumatic hose valve at each hand-hose station; the water-deluge valve in turn starts the foam liquid and fire pumps and trips the companion valve. Foam solution then flows to all the hose stations on that header. As with the sprinkler systems, proportioning is by means of orifice plates in the foam liquid line.

Installation Tests

Tests were held August 6 to demonstrate the operation of the foam systems, with 350 interested spectators. Because the Overhaul Hangar had been put into service immediately upon its completion, no working foam tests were conducted on its systems. The tests were conducted in the Line Maintenance Hangar, considerably farther from the supply, and the results confirmed that the pressure and volume in the Overhaul Hangar would exceed the calculated requirement.

Prior to the public tests, preliminary water flow tests were run in the then partly completed Line Maintenance Hangar. Using water only, system

Showing hose used for cleanup.

Foam Blanket at conclusion of the Test illustrates the depth of the foam build-up within a 3-minute period.

discharge tests were made, to check pump curves and calculated orifice sizes and to revise calculations where necessary; actual water pressure readings were recorded at the pumps, deluge valves and sprinkler heads. Since the final tests were to be made with four systems operating (to avoid unnecessary usage of the foam liquid), six-system operation was also tested.

During the formal tests on August 6, the largest of the four remote systems was operated for a three-minute period, during which time-pressure readings and foam samples were taken. Following this, the remaining three systems were actuated and all four systems were allowed to discharge for a further three-minute period, while additional samples were collected. Even during the limited duration of the foam discharge, the systems demonstrated the thick smothering blanket of foam that would be put down by the foam-water sprinklers.

When the foam discharge was complete, two of the four systems were shut off, while the remaining two were allowed to operate with water alone for a further three-minute interval. This comparison allowed the observers the opportunity to examine the stability of the foam blanket under continuing water discharge. In spite of the short duration of foam discharge, no visible breakdown of the foam blanket was observed during the water discharge.

Upon completion of the test, total cleanup with no trace of the six-inch foam blanket (other than a few damp patches on the floor) was made within two hours by four men. Using fire hoses, a large scraper, and making full use of the large storm sewers provided as floor drains, complete removal of foam was accomplished in a time that astounded many of the test observers.

Summary

Canada, we feel, is becoming an acknowledged leader in the field of foam-water sprinkler protection in airplane hangars, both commercial and military.

With its Foam-Water Sprinkler System in operation at the Montreal base, Trans-Canada Air Lines feels confident that its tremendous investment is as effectively protected from fire damage as present-day fire protection engineering knowledge makes possible.

Trans-Canada Air Lines commends the work of two groups in the design and construction of this protection: Jas. P. Keith and Associates, the Montreal firm of Consulting Engineers who supervised the original design and specifications for this project and, also, the "Automatic" Sprinkler Company of Canada, Limited, whose Montreal staff carried out the final engineering, installation and testing of this system in its entirety.

Fires and Fire Losses Classified, 1959

Editor's Note: During recent years NFPA members have called attention to instances where certain parts of this article, notably Table VI, have been taken out of context and misused in advertisements and otherwise. Readers are reminded that material published in the QUARTERLY is copyrighted and may not be reproduced in whole or in part without written permission from the Association. This article is available from the Association in pamphlet form.

There were approximately 2,114,360 fires of all types in the United States in 1959 causing a loss of $1,439,640,000, according to estimates compiled by the National Fire Protection Association. The 1959 loss was an increase from that of 1958 when the estimated loss was $1,278,808,000. This is the worst loss record in U. S. history. The 2,114,360 fires in 1959 were 120,785 more than in 1958.

Two-thirds of the jump in the monetary loss figure was due to a change in the method of calculating forest fire losses by the Forest Service of the U. S. Department of Agriculture. Had this method been used in the 1958 fire loss figure, the 1958 total would have been $1,385,308,000.

Building fires in the U. S. in 1959 totaled 883,300 and caused $1,083,210,000 damage. An additional 1,231,060 fires not involving buildings — aircraft, motor vehicles, forests, ships, rubbish, grass fires, etc. — accounted for an estimated $356,430,000. Building fire estimates for 1958, reported in the October 1959 QUARTERLY, showed 866,700 fires with $1,056,308,000 loss.

The 1959 occupancy experience, shown in Table V, has been expanded to include new occupancy groupings. This expansion is in keeping with improved reporting by the State Fire Marshals. The occupancy list has been rearranged to be consistent with the NFPA Building Exits Code occupancy categories. Two of the notable changes in the 1959 occupancy experience (Table V) from that of 1958 were in the forest fires and apartments categories. The tremendous 1959 dollar losses in the west coast forests were reflected in the $35,220,000 additional loss reported in the adjusted forest figures. Eastern and southern areas of the United States were responsible for most of the 6,700 increase in numbers of forest fires. Apartment fires were responsible for 2,800 more fires and a dollar increase of $8,887,500. Other increases include a $7,000,000 rise in aircraft losses. The most encouraging decrease was a $3,891,000 drop in school fire losses accompanied by a drop of 200 fires.

Building fire losses by cause are estimated in Table VI. Principal changes in the 1959 experience involved fires attributed to spontaneous ignition and fires caused by children and matches. Fires started by spontaneous ignition increased 8.8 per cent in number and $2,629,000 in total loss. There were 8.7 per cent more children and matches fires, and the loss from such fires increased $1,015,000. Fires caused by sparks on roofs reversed their long downward trend, rising 2,600 to 11,900 in 1959.

Methods of Compiling Data

The data from which Tables I to IV were compiled were obtained from 15

(Continued on page 201)

TABLE I. Number of Fires by Occupancies in Fourteen States — 1959

	Conn.	Ill.[2]	Iowa	Kans.	La.	Minn.[7]	Mont.	N. H.	N. D.[2,4,6]	Ohio	Oreg.[4,9]	S. D.[1]	Wisc.[8]	Wyo.	Totals
PUBLIC ASSEMBLY OCCUPANCIES															
Amusement, recreation halls	...	63	2	11	...	15	...	...	...	...	...	...	...	1	92
Bowling alleys	...	25	3	...	...	...	4	...	...	...	...	...	28	...	60
Churches	4	77	16	18	43	15	4	7	4	69	36	5	100	5	403
Clubs, club houses	11	...	9	...	...	2	3	4	...	...	...	...	57	2	88
Restaurants, taverns	44	435	81	7	...	76h	32	25	...	270	144	19h	734	26	1,893
Theaters, including motion picture	1	16	2	12	15	4	1	1	...	12	5	...	36	...	105
Other public assembly occupancies	...	39	19	23	...	13	6	4	...	14	31	4	38p	4c	197
EDUCATIONAL OCCUPANCIES	13	57	22	19	58	24	6	4	3	62	52	8	146	...	474
INSTITUTIONAL OCCUPANCIES															
Hospitals	3	16	3	9d	32	4	1	2	...	59	...	2d	23	1	155
Other institutional occupancies	1	1	5	...	...	...	...	2	1	13	5	...	...	4	32
RESIDENTIAL OCCUPANCIES															
Apartments	237	2,021b	155	86	...	223c	31	72	...	1,557	...	16	212	24	4,634
Dwellings, one and two family	809	5,254	1,167	1,359	4,489	1,356	348	698	321i	6,604	12,774i	453	27,989	526	64,147
Hotels	17	199c	12	42	248g	61	26	15	25j	133	317m	34n	136	22	1,287
Motels	...	...	3	11	...	...	7	3	...	19	...	...	84	11	138
Rooming, boarding houses	25	...	3	11	...	...	7	4	...	103	...	...	54	...	207
Summer cottages, camps	13	...	...	...	...	...	3	63	...	...	...	...	30	...	109
Trailers, trailer courts	...	102	50	...	...	...	3	7	...	229	...	21	105	...	517
Other residential occupancies	...	2	8	...	...	...	...	2	...	...	...	...	2	...	14
MERCANTILE OCCUPANCIES															
Food stores, incl. supermarkets	...	...	25	...	...	...	8	...	...	...	...	...	14	10	57
Service stations	6	118	23	52f	...	37f	4	6	...	96	22	57f	63	21	505
Other mercantile occupancies	53	728	98	170	486	230	28	78	39	563	418k	115	800	36	3,842
OFFICE OCCUPANCIES															
Government buildings	...	...	1	...	...	...	...	4	41	48	...	...	...	...	94
Office buildings, banks, other office occupancies	5	135	20	21	...	22	5	...	68	69	...	4	144	16	509
INDUSTRIAL OCCUPANCIES															
Chemical, chemical products	...	2	...	9	75	...	...	1	3	...	7	...	...	...	97
Food, food products	1	40	19	15	49	8	1	5	37	20	71	4	90	6	366
Metal, metal products	3	16	15	16	22	20	2	7	3	...	18	...	41	...	163
Wood, wood products	3	10	1	3	23	...	...	9	2	...	164	...	20	...	235
Other industrial operations	5	85	66	34	68	36	23	37	22	185	40	16	187	7	811
Other industrial buildings, occupancy not reported	66	499	78	...	33	109	6	18	...	448	50	...	333	4	1,644
STORAGE OCCUPANCIES															
Barns	120a	434	214	647e	314	211	5	29	272a	403	219a	61	1,694	...	4,623
Farm property, other	...	677	124	...	...	132	25	76	...	383	...	16	5,957	...	7,390
Garages, residential parking	80	1,080	160	...	8	393	26	23	...	766	32	...	347	22	2,937
Grain elevators	...	15	9	8	...	21	3	...	...	...	29	10	61	3	159
Grain, feed, seed, hay storage	...	23	13	1	...	20	...	...	...	41	...	4	...	...	102
Lumberyards	2	18	3	3	12	16	5	2	2	...	...	...	24	...	87
Other storage occupancies	25	164	166	29	78	90	13	15	10	184	30	10	195	22	1,031
Other buildings and occupancies not reported	211	514	...	1	68	79	13	1	...	1,150	...	10	91	1	2,139
OTHER THAN BUILDING FIRES															
Outdoor fires, not involving transportation	...	163	43	...	...	3	6	...	...	210	...	129	...	131	685
Transportation fires	218	2,523	575	494	925	272	8	...	...	3,862	727	215	2,472	331	12,622
Totals	1,976	15,551	3,213	3,111	7,046	3,494	663	1,224	853	17,572	15,191	1,213	42,307	1,236	114,650

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[4] Number of insurance claims.
[6] No losses less than $100.
[7] No losses less than $25.
[8] Includes all lightning losses.
[9] Includes Roseburg Explosion.

a. Includes other farm property.
b. Includes flats and rooming houses.
c. Includes boarding houses.
d. Includes homes for the aged.
e. Includes residential parking garages.
f. Includes repair garages.
g. Includes motels, boarding houses, clubs.
h. Includes night clubs.
i. Includes flats and apartments.
j. Includes clubs and theaters.
k. Includes office buildings.
m. Includes motels and rooming houses.
n. Includes motels.
p. Includes halls.

TABLE II. Fire Losses by Occupancies in Eleven States — 1959

Losses were reported by the states to the nearest dollar. They are reported in thousands in this table.

	Conn.	Ill.[2]	Iowa	Kans.	La.	Minn.[7]	N. Dak.[2,3,6]	Ohio	Oreg.[3,9]	S. Dak.[1]	Wisc.[5]	Totals
PUBLIC ASSEMBLY OCCUPANCIES												
Amusement, recreation halls	$	439.9	2.9	116.3	$	106.7	$	$	$	$	$	$ 665.8
Bowling alleys	.....	106.6	109.8	.....	.....	.....	.....	.....	.....	.....	474.1	690.5
Churches	238.6	2,422.3	205.8	18.7	341.2	29.9	15.7	546.4	44.6	1.2	304.4	4,168.8
Clubs, club houses	26.1	.....	338.5	.....	.....	0.8	.....	.....	.....	.....	78.3	443.7
Restaurants, taverns	275.3	1,505.5	955.2	72.6	.....	350.8h	.....	917.0	339.6	86.7h	838.8	5,341.5
Theaters, including motion picture	10.0	47.5	9.5	146.4	80.3	63.4	.....	168.9	2.5	.....	116.1p	644.6
Other public assembly occupancies	.....	70.3	32.3	13.6	.....	203.8	.....	25.5	19.9	12.0	11.2	388.6
EDUCATIONAL OCCUPANCIES	134.0	820.0	173.9	388.9	458.3	463.6	5.1	507.6	124.0	16.3	209.0	3,300.7
INSTITUTIONAL OCCUPANCIES												
Hospitals	0.9	17.5	20.8	2.2d	836.6	4.4	.....	13.5	.....	0.3d	8.8	905.0
Other institutional occupancies	1.2	.....	70.5	.....	.....	.....	5.5	16.6	4.1	.....	.....	97.9
RESIDENTIAL OCCUPANCIES												
Apartments	972.6	4,082.8b	368.8	202.2	.....	361.2e	.....	2,157.6	.....	10.7	191.5	8,347.4
Dwellings, one and two family	2,130.5	10,738.6	2,883.8	1,227.8	6,404.8	3,274.3	333.0i	12,025.5	7,025.9i	677.4	7,279.5	54,001.1
Hotels	135.9	352.3c	2.7	41.3	374.9g	1,165.2	37.6j	179.6	1,130.9m	76.8n	209.9	3,907.1
Motels	.....	.....	0.9	41.4	.....	.....	.....	63.6	.....	.....	16.9	122.8
Rooming, boarding houses	163.3	.....	0.5	27.9	.....	.....	.....	410.7	.....	.....	67.1	669.5
Summer cottages, camps	70.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.7	88.0
Trailers, trailer courts	.....	108.7	77.1	.....	.....	.....	.....	370.4	.....	30.7	57.7	644.6
Other residential occupancies	.....	6.6	8.1	.....	.....	.....	.....	.....	.....	.....	.....	14.7
MERCANTILE OCCUPANCIES												
Food stores, incl. supermarkets	.....	.....	247.4	.....	.....	.....	.....	.....	.....	.....	8.6	256.0
Service stations	51.7	276.4	27.5	171.0f	.....	510.0f	.....	84.1	64.5	317.7f	27.8	1,530.7
Other mercantile occupancies	323.0	4,736.8	1,080.1	814.8	2,043.0	2,045.1	143.8	2,574.1	1,877.2k	1,291.6	2,894.8	19,824.3
OFFICE OCCUPANCIES												
Government buildings	.....	.....	5.6	.....	.....	.....	78.9	704.2	.....	.....	.....	788.7
Office buildings, banks, other office occupancies	11.4	341.3	57.2	893.4	.....	54.8	298.2	89.1	.....	3.8	62.0	1,811.2
INDUSTRIAL OCCUPANCIES												
Chemical, chemical products	.....	1.0	.....	359.7	347.7	.....	1.7	.....	20.0	.....	.....	730.1
Food, food products	.....	413.3	143.3	429.6	1,066.3	67.9	137.7	35.4	797.3	3.4	202.6	3,296.8
Metal, metal products	2.1	20.5	193.2	26.6	33.3	41.7	10.5	.....	27.7	.....	64.5	420.1
Wood, wood products	8.3	16.2	0.6	1.2	216.9	.....	1.4	.....	4,838.2	.....	45.2	5,128.0
Other industrial operations	359.1	1,605.2	677.0	88.5	237.4	560.6	123.9	559.6	178.9	15.1	714.9	5,120.2
Other industrial buildings, occupancy not reported	798.5	6,027.9	943.1	.....	120.2	2,508.5	.....	2,950.3	131.0	.....	1,942.4	15,421.9
STORAGE OCCUPANCIES												
Barns	731.1a	2,749.6	1,233.5	1,105.2e	551.2	1,211.7	356.8a	2,939.3	497.9a	244.5	3,963.9	15,584.7
Farm property, other	.....	1,074.8	324.3	.....	.....	277.7	.....	514.6	.....	36.0	982.1	3,209.5
Garages, residential parking	.....	.....	176.6	.....	.....	406.6	.....	866.2	.....	.....	.....	1,449.4
Grain elevators	.....	434.2	407.8	106.4	.....	269.2	808.3	.....	1,855.8	307.7	770.2	4,959.6
Grain, feed, seed, hay storage	.....	434.4	52.6	0.3	.....	11.8	.....	655.6	.....	6.2	.....	1,160.9
Lumberyards	7.9	621.3	59.4	91.4	137.2	254.7	9.2	.....	.....	.....	119.9	1,301.0
Other storage occupancies	586.6	777.6	629.4	88.3	328.7	514.1	60.1	754.3	650.5	339.9	1,116.1	5,845.6
Other buildings, and occupancies not reported	1,577.2	972.0	.....	0.1	420.3	214.0	.....	4,886.5	.....	9.8	83.3	8,163.2
OTHER THAN BUILDING FIRES												
Outdoor fires, not involving transportation	.....	49.9	14.1	.....	.....	1.7	.....	54.9	.....	50.0	.....	170.6
Transportation fires	92.4	861.3	391.7	168.2	319.9	244.3	.....	4,527.5	124.3	63.3	486.4	7,279.3
Totals	$8,708.0	$42,332.3	$11,925.5	$6,644.0	$14,318.2	$15,218.5	$2,427.4	$39,598.6	$19,754.8	$3,601.1	$23,365.7	$187,894.1

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[3] Insured losses only.
[4] No losses less than $100.
[5] No losses less than $25.
[6] Includes all lightning losses.
[9] Includes Roseburg Explosion.

a. Includes other farm property.
b. Includes flats and rooming houses.
c. Includes boarding houses.
d. Includes homes for the aged.
e. Includes residential parking garages.
f. Includes repair garages.
g. Includes motels, boarding houses, clubs.
h. Includes night clubs.
i. Includes flats and apartments.
j. Includes clubs and theaters.
k. Includes office buildings.
m. Includes motels and rooming houses.
n. Includes motels.
p. Includes halls.

Totals	$8,708.0	$42,332.3	$11,925.5	$6,644.0	$14,318.2	$15,218.5	$2,427.4	$39,598.6	$19,754.8	$3,601.1	$23,365.7	$187,894.1

[1] Fiscal year ended June 30, 1960.
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[3] Insured losses only.
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a. Includes other farm property.
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g. Includes motels, boarding houses, clubs.
h. Includes night clubs.
i. Includes flats and apartments.
j. Includes clubs and theaters.
k. Includes office buildings.
m. Includes motels and rooming houses.
n. Includes motels.
p. Includes halls.

TABLE III. Number of Fires by Causes in Fourteen States — 1959

	Conn.	Ill.[2]	Iowa	Kans.	La.	Mich.	N. H.	N. D.[3,4,6]	Ohio	Ore.[4,9]	R. I.[5]	S. D.[1]	Wisc.[8]	Wyo.	Totals
Heating and cooking (See also flammable liquid appliances; gas and appliances)															
Oil-fired equipment defective or overheated	111	...	70	...	80	2,038	127	26	...	...	55	30	343	...	2,880
Gas-fired equipment defective or overheated	...	...	4	...	280	603	7	25	...	...	...	...	108	...	1,027
Other equipment, incl. solid fuels, and unknown types	38	1,320a	147	199a	56	3,665	82	10	...	886a	75b	74b	1,145	118a	7,815
Chimneys, flues defective or overheated	35	696	128	52	50	1,403	137	27	...	779	55	33	1,139	26	4,560
Hot ashes and coals	13	322	23	23	...	259	5	...	...	1,010	1	2	110	105	1,873
Combustibles near heaters	3	85	110	...	...	...	6	49	...	...	...	2	582	49	886
Smoking and matches	302	2,900	359	383	826	4,950	139	79	2,848	3,492	90	109	6,946	172	23,595
Electrical															
Fixed services, fires due to wiring, equipment, etc.	147	2,012	439	394	1,059d	2,533	108	121d	2,496d	1,186	141d	175	3,077	132	14,020
Power consuming appliances	139	468	181	17	...	3,788	96	...	...	1,423	...	85	2,354	104	8,655
Rubbish, source of ignition unknown	...	1,229	1	229	...	7,861	11	...	...	43	14	...	159	...	9,547
Flammable liquids															
Appliances, incl. lamps, blowtorches, etc.	13	...	...	...	...	...	12	...	...	...	70	2	72	...	169
Miscellaneous other flammable liquid fires	68	483c	171c	262c	...	557c	96	...	...	2,455c	14	65	1,982	118c	6,271
Open flames and sparks															
Sparks on roof	...	144	...	12	...	412	...	...	...	167	...	...	...	...	735
Welding and cutting	...	...	44	...	25	...	11	7	114	...	...	4	53	48	306
Sparks from machinery, friction	...	473	20	10	30	155	19	11	...	...	...	8	49	23	798
Thawing pipes	2	...	10	...	...	...	6	...	...	...	...	4	20	...	42
Miscellaneous open flames and sparks	33	555	23	86	627	456	46	19	3,136	375	76	109	1,167	...	6,708
Lightning	56	279	113	72	521	813	94	37	281	44	20	67	19,325e	12	21,734
Children and matches	99	...	152	...	...	2,458	59	...	...	255	76	49	428	119	3,695
Exposure	25	810	152	186	461	231	8	36	299	808	4	23	197	19	3,259
Incendiary, suspicious	77	139	35	28	151	1,223	17	1	...	75	77	3	132	10	1,968
Spontaneous ignition	25	290	76	13	28	2,887	28	20	412	104	21	28	208	19	4,159
Gas and appliances, incl. gas explosions	...	339	25	50	...	...	7	...	...	140	...	26	...	32	619
Explosions, miscellaneous and unclassified	13	142	35	74	...	...	...	...	...	874f	...	31	920	1	2,090
Miscellaneous known causes	447	914	112	209	54	16,821	16	129	5,265	25	177	11	266	...	24,446
Unknown or undetermined	257	2,029	481	933	2,446	7,021	51	251	1,634	1,029	198	179	1,267	103	17,879
Fireworks, firecrackers and rockets	...	22	...	4	7	...	...	1	...	21	1	8	14	24	102
Totals	1,903	15,651	2,911	3,236	6,701	60,134	1,188	849	16,485	,191	1,165	1,127	42,063	1,234	169,838

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[4] Number of insurance claims.
[5] Fiscal year ended Sept. 30, 1959.
[6] No losses less than $100.
[8] Includes all lightning losses.
[9] Includes Roseburg Explosion.

a. Includes all types of heating and cooking equipment.
b. Includes gas-fired heating and cooking equipment.
c. Includes flammable liquid appliances.
d. Includes electrical power consuming appliances.
e. Includes all lightning damage.
f. Includes Roseburg Explosion.

TABLE IV. Fire Losses by Causes in Ten States — 1959

Losses were reported by the states to the nearest dollar. They are reported in thousands in this table.

	Conn.	Ill.[2]	Iowa	Kans.	La.	N. Dak.[2,3,6]	Ohio	Oreg.[3,9]	S. Dak.[1]	Wisc.[8]	Totals
Heating and cooking (See also flammable liquid appliances; gas and appliances)											
Oil-fired equipment defective or overheated	$ 355.1	$	$ 126.8	$	$ 106.1	$ 66.0	$	$	$ 52.2	$ 213.0	$ 919.2
Gas-fired equipment defective or overheated	.....	.....	2.3	.....	823.9	124.5	.....	.....	.....	88.1	1,038.8
Other equipment, incl. solid fuels, and unknown types	96.9	2,201.5a	507.5	412.2a	60.9	24.0	.....	691.7a	300.5b	1,873.4	6,168.6
Chimneys, flues defective or overheated	35.7	1,361.2	331.3	35.2	92.8	59.0	.....	594.8	66.1	460.7	3,036.8
Hot ashes and coals	20.0	396.2	64.8	13.9	.....	.....	.....	938.7	.5	61.7	1,495.8
Combustibles near heaters	.9	2,487.0	304.0	.....	.....	32.4	.....	.....	.1	107.8	2,932.2
Smoking and matches	508.3	4,512.0	448.7	183.6	383.4	107.3	3,128.9	560.7	532.3	1,476.2	11,841.4
Electrical											
Fixed services, fires due to wiring, equipment, etc.	693.8	4,693.1	2,463.8	481.7	1,967.1d	257.4d	4,802.7d	3,102.5	423.6	4,609.3	23,495.0
Power consuming appliances	278.5	734.7	471.3	6.8	.....	.....	.....	934.0	97.9	659.3	3,182.5
Rubbish, source of ignition unknown	.....	2,297.1	.8	127.2	.....	.....	.....	58.8	.....	98.7	2,582.6
Flammable liquids											
Appliances, incl. lamps, blowtorches, etc.	27.8	.....	.....	.....	.....	.....	.....	.....	1.2	120.3	149.3
Miscellaneous other flammable liquid fires	304.8	1,134.4c	535.3c	234.1c	.....	.....	.....	528.3c	91.3	622.0	3,450.2
Open flames and sparks											
Sparks on roof	.....	146.6	.....	10.5	.....	.....	.....	153.9	.....	.....	311.0
Welding and cutting	.....	.....	75.3	.....	803.4	13.6	173.3	.....	2.1	211.5	1,279.2
Sparks from machinery, friction	.....	755.7	73.9	50.6	53.3	621.9	.....	.....	13.1	414.3	1,982.8
Thawing pipes	3.6	.....	6.1	.....	.....	.....	.....	.....	3.2	11.1	24.0
Miscellaneous open flames and sparks	65.0	728.3	95.6	106.5	387.9	60.7	5,053.5	94.8	195.9	839.3	7,627.5
Lightning	173.4	1,037.5	643.7	154.3	1,111.3	35.2	404.4	75.8	64.1	2,750.5e	6,450.2
Children and matches	290.1	.....	127.7	.....	.....	.....	.....	181.0	111.3	370.4	1,080.5
Exposure	120.1	1,083.5	828.2	134.3	582.0	34.1	456.9	1,260.8	118.5	210.5	4,828.9
Incendiary, suspicious	488.2	324.0	64.0	43.4	854.1	3.2	.....	218.4	7.5	1,643.6	3,646.4
Spontaneous ignition	107.4	1,293.0	279.5	13.7	137.2	66.3	1,118.0	272.9	63.8	1,613.7	4,965.5
Gas and appliances, incl. gas explosions	.....	484.2	40.8	74.3	.....	.....	.....	66.1	96.2	.....	761.6
Explosions, miscellaneous and unclassified	58.0	2,742.4	410.9	406.1	.....	.....	.....	2,829.6f	107.0	778.0	7,332.0
Miscellaneous known causes	2,117.9	2,112.8	332.2	219.6	205.4	225.7	13,038.9	14.5	7.1	147.7	18,421.8
Unknown or undetermined	2,857.7	12,790.4	3,394.9	3,912.1	6,566.6	692.1	8,707.1	7,169.3	1,204.2	3,592.6	50,887.0
Fireworks, firecrackers and rockets	.....	16.5	.....	24.2	2.9	.5	.....	8.0	3.2	.6	55.9
Totals	$8,603.2	$43,332.1	$11,629.4	$6,644.3	$14,138.3	$2,423.9	$36,883.7	$19,754.6	$3,562.9	$22,974.3	$169,946.7

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[3] Insured losses only.
[6] No losses less than $100.
[8] Includes all lightning losses.
[9] Includes Roseburg Explosion.

a. Includes all types of heating and cooking equipment.
b. Includes gas-fired heating and cooking equipment.
c. Includes flammable liquid appliances.
d. Includes electrical power consuming appliances.
e. Includes all lightning damage.
f. Includes Roseburg Explosion.

state fire marshals' reports for the year 1959 or the closest fiscal year thereto.

While the methods of reporting and tabulating fire loss figures differ from state to state, the volume of statistics from the 15 typical states chosen, representing all sections of the country and including both primarily agricultural and industrial states, is sufficiently large to indicate the relative distribution of fires and fire losses. Table I shows the number of fires by occupancy in 14 states and Table II the loss by occupancy in 11 states. Tables III and IV list the number of fires and loss by cause in 14 and 10 states respectively.

Tables V and VI, showing the nationwide distribution of fires and losses by occupancy and cause, are based primarily on typical state experience enumerated in Tables I to IV. Table VII summarizes statistics from all state reports received.

Various sources have furnished figures for items in Table V. Railroad losses were furnished by the Association of American Railroads, Fire Protection and Insurance Section. Statistics on aircraft fires were compiled by reference to the NFPA aircraft fire loss records. Motor vehicle, and rubbish, grass, and brush fire data are based on the annual NFPA survey of U. S. cities (Fire Record of Cities, April, 1960 QUARTERLY). The estimate of the number of forest fires was compiled by the Forest Service of the United States Department of Agriculture.

As will be seen in Table VII, 22 states with a population of 68,710,000 reported a total of 214,660 fires. Experience indicates that this is less than half the actual number of fires in these states. Some states, for example, do not report fires with uninsured losses, others report only fires with losses in excess of $25.

To obtain national estimates of the number of fires by occupancy, 100 per cent was added to the number reported by the 14 states shown in Table I. Making use of this figure and population ratios, the number of fires by occupancy in the United States was calculated. Further adjustments were made based upon other surveys of 1959 fire experience. Following a similar procedure with the state experience shown in Table III, national estimates of the numbers of fires by cause were obtained.

To obtain the estimated national fire loss by occupancy and cause, the population ratio was applied to the loss of the states shown in Tables II and IV. To account for losses not reported through the usual channels, 33⅓ per cent was added as in the previous years. Further adjustment was necessary in a few instances because of the unusually large damage caused by the 1959 large loss fires.

Improved Occupancy List

In order to take advantage of the increased data available from the state fire marshals' reports and the occupancy breakdown offered by the NFPA Building Exits Code, all data submitted this year were kept in the original occupancy divisions until the analysis was completed. Then the occupancies in which a statistically significant amount of data were available were grouped in accordance with the Building Exits Code. The result is shown in Table V. In order to remain within the space limitations of the article, Tables I and II were further condensed. It is hoped that the new occupancy listing used in Table V will serve as a useful guide to those classifying fires by occupancy. Further occupancy breakdown within major groups will be made in these annual reports when statistically significant data become available.

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[3] Insured losses only.
[4] No losses less than $100.
[5] Includes all lightning losses.
[6] Includes Roseburg Explosion.

a. Includes all types of heating and cooking equipment.
b. Includes gas-fired heating and cooking equipment.
c. Includes flammable liquid appliances.
d. Includes electrical heating and cooking appliances.
e. Includes all lightning damage.
f. Includes Roseburg Explosion.

Table V. Estimated Distribution of U. S. Fire Losses by Occupancies, 1959

These estimated figures are intended to show the relative order of magnitude of fire losses by occupancies, and while they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class. As explained in the text, 100 per cent has been added in estimating the number of fires, and 33⅓ per cent has been added to the losses to cover unreported losses. Any reproduction of these figures should identify them as "National Fire Protection Association estimates."

	No. of Fires		Losses	
PUBLIC ASSEMBLY OCCUPANCIES	30,300		$ 75,180,000	
Amusement, recreation halls		1,700		$ 5,550,000
Auditoriums		800		2,250,000
Bowling alleys		1,200		7,650,000
Churches		3,400		17,530,000
Clubs, club houses		2,200		5,280,000
Restaurants, taverns		17,500		29,880,000
Terminals, passenger		1,000		1,200,000
Theaters, including motion picture		900		3,860,000
Other public assembly buildings		1,600		1,980,000
EDUCATIONAL OCCUPANCIES	3,800		20,090,000	
Schools		2,900		17,350,000
Colleges and other educational buildings		900		2,740,000
INSTITUTIONAL OCCUPANCIES	2,300		3,390,000	
Homes for the aged		500		940,000
Hospitals		1,300		1,960,000
Other institutional buildings		500		490,000
RESIDENTIAL OCCUPANCIES	609,100		390,890,000	
Apartments		37,700		42,150,000
Dwellings, one and two family		542,000		312,000,000
Hotels		10,800		21,020,000
Motels		2,400		1,770,000
Rooming, boarding houses		4,300		3,550,000
Summer cottages, camps		5,100		3,250,000
Trailers, trailer courts		6,500		5,600,000
Other residential buildings		300		1,550,000
MERCANTILE OCCUPANCIES	41,300		101,050,000	
Clothing, dry goods stores		1,400		16,460,000
Drug stores		1,000		1,400,000
Food stores, incl. supermarkets		2,600		17,680,000
Furniture stores		1,000		14,890,000
Laundries, self-service		1,800		2,760,000
Service stations		4,000		4,840,000
Shoe, shoe repair stores		1,900		1,630,000
Other mercantile buildings		27,600		41,390,000
OFFICE OCCUPANCIES	8,400		29,360,000	
Government buildings		1,900		11,540,000
Office buildings, banks, other office occupancies		6,500		17,820,000

(Continued on page 203)

Table V. Continued

	No. of Fires		Losses	
INDUSTRIAL OCCUPANCIES	48,100		$183,810,000	
Chemical, chemical products		1,900		9,660,000
Food, food products		6,700		30,120,000
Bakeries		800		2,010,000
Dairies, creameries		1,800		6,520,000
Flour mills		1,100		7,090,000
Meat packing		800		1,930,000
Other food processing		2,200		12,570,000
Metal, metal products		2,600		19,190,000
Minerals, mineral products		600		3,260,000
Paper, paper products		1,100		3,880,000
Photography, printing		900		4,360,000
Textiles, textile products		7,400		10,900,000
Wood, wood products		4,100		28,260,000
Other industrial operations		10,400		14,780,000
Dry cleaning plants		1,300		2,150,000
Electric generating plants, substations, transformers		1,100		3,480,000
Garages, repair and public parking		4,400		4,450,000
Laundries		2,300		4,050,000
Water works, pumping stations		1,300		650,000
Other industrial buildings, occupancy not reported		12,400		59,400,000
STORAGE OCCUPANCIES	127,100		227,160,000	
Barns		39,100		81,100,000
Farm property, other		54,500		24,800,000
Garages, residential parking		21,100		15,600,000
Grain elevators		2,200		29,670,000
Grain, feed, seed, hay storage		1,200		5,170,000
Lumberyards		1,600		21,750,000
Petroleum bulk plants		500		960,000
Other storage buildings		6,900		48,110,000
OTHER BUILDINGS, OCCUPANCIES NOT REPORTED	12,900		52,280,000	
TOTAL (BUILDING FIRES)	883,300		$1,083,210,000	
OTHER THAN BUILDING FIRES	1,231,060		356,430,000	
Brush, rubbish, grass		903,000		.....
Forest fires		104,600		166,220,000
Other outdoor fires		6,100		1,740,000
Aircraft		160		150,000,000
Construction equipment, farm tractors		6,900		3,030,000
Motor vehicles		204,200		22,000,000
Railroad rolling stock, incl. all railroad property		4,700		11,820,000
Other transportation fires		1,400		1,620,000
GRAND TOTAL	2,114,360		$1,439,640,000	

Table VI. Estimated U. S. Building Fire Losses by Causes, 1959

These estimated figures are intended to show the relative order of magnitude of fire losses by causes, and to indicate year-to-year trends. While they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class. These figures by themselves do not show the relative safety in utilization of various types of material, devices, fuels or services and should not be used for this purpose. Reproduction of this Table in whole or part is not authorized without written permission from the Association, and identification of figures as "National Fire Protection Association estimates."

	No. of Fires		Losses	
Heating and cooking (See also Flammable liquid appliances; gas and appliances)		202,000		$ 137,760,000
Oil-fired equipment defective or overheated	47,400		$31,870,000	
Gas-fired equipment defective or overheated	19,800		16,420,000	
Other equipment, incl. solid fuels, and unknown types	58,200		46,580,000	
Chimneys, flues defective or overheated	43,200		24,660,000	
Hot ashes and coals	18,800		8,750,000	
Combustibles near heaters	14,600		9,480,000	
Smoking and matches		159,300		75,560,000
Electrical		122,900		193,220,000
Fixed services, fires due to wiring, equipment, etc.	74,000		133,980,000	
Power consuming appliances	48,900		59,240,000	
Rubbish, source of ignition unknown		57,000		21,000,000
Flammable liquids		57,600		40,750,000
Appliances, incl. lamps, blow torches, etc.	7,000		5,990,000	
Miscellaneous other flammable liquid fires	50,600		34,750,000	
Open flames and sparks		53,300		75,640,000
Sparks on roof	11,900		5,660,000	
Welding and cutting	5,000		14,320,000	
Sparks from machinery, friction	5,700		18,120,000	
Thawing pipes	2,100		2,910,000	
Miscellaneous open flames and sparks	28,600		34,630,000	
Lightning		29,400		26,590,000
Children and matches		34,600		22,380,000
Exposure		24,600		30,300,000
Incendiary, suspicious		20,300		27,730,000
Spontaneous ignition		22,900		29,800,000
Gas and appliances, incl. gas explosions		11,800		12,100,000
Explosions, miscellaneous and unclassified		8,000		33,050,000
Fireworks		1,500		590,000
Miscellaneous known causes		21,100		44,150,000
Unknown or undetermined		57,000		312,570,000
TOTALS		883,300		$1,083,210,000

Table VII. Fires per 1000 Population and Fire Loss per Person for Twenty-two States, 1959, as Reported by Fire Marshals

State	Population 1960 Est.	No. of Fires	Fires Per 1000 Pop.	Fire Loss	Fire Loss Per Person
Connecticut	2,517,000	1,976	0.78	$ 8,708,207	$3.46
Delaware	443,000	5,469	12.32	3,024,582	6.83
Illinois[2]	10,006,000	15,551	1.56	42,332,000	4.23
Iowa	2,743,000	3,213	1.17	11,925,389	4.34
Kansas	2,178,000	3,111	1.43	6,644,029	3.05
Louisiana	3,234,000	7,046	2.17	14,318,144	4.44
Massachusetts	5,115,000	12,057	2.36	36,003,215	7.05
Michigan	7,778,000	60,114	7.74	44,222,790	5.68
Minnesota[7]	3,391,000	3,494	1.03	15,218,412	4.50
Montana	670,000	706	1.05	3,462,835	5.18
Nebraska	1,405,000	2,135	1.52	6,335,093	4.50
New Hampshire	601,000	1,224	2.03	5,290,095	8.79
New Mexico	944,000	5,944	6.28	4,253,670	4.51
North Dakota[2,3,4,6]	627,000	853	1.36	2,427,347	3.87
Ohio	9,647,000	17,572	1.82	39,598,284	4.11
Oregon[3,4,9]	1,758,000	15,191	8.64	19,754,687	11.20
Rhode Island[3]	842,000	1,880	2.23	4,308,129	5.13
South Dakota[1]	677,000	1,213	1.79	3,601,041	5.31
Texas[3]	9,489,000	11,500	1.21	39,786,710	4.19
Vermont[1,3,4]	387,000	868	2.24	2,131,188	5.51
Wisconsin[8]	3,930,000	42,307	10.76	23,365,697	5.94
Wyoming	328,000	1,236	3.77	1,226,506	3.73
	68,710,000	214,660	3.13	$337,938,050	$4.91

[1] Fiscal year ended June 30, 1960.
[2] Fiscal year ended June 30, 1959.
[3] Insured losses only.
[4] Number of insurance claims.
[5] Fiscal year ended September 30, 1959.
[6] No losses less than $100.
[7] No losses less than $25.
[8] Includes all lightning losses.
[9] Includes Roseburg Explosion.

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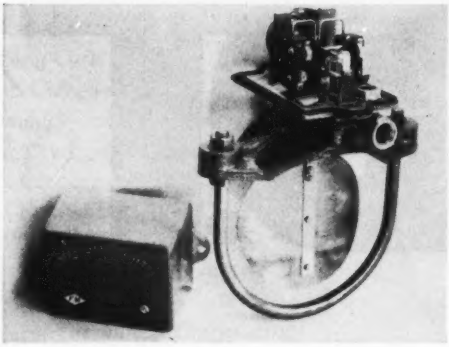

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This device is approved by Factory Mutual Laboratories and Underwriters' Laboratories, Inc.

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5-inch size shown above. To install simply drill 2-inch hole in pipe.

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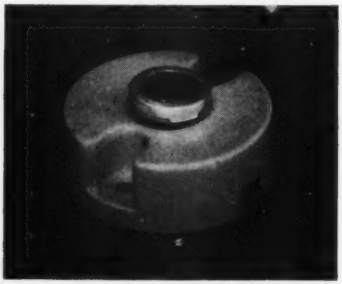

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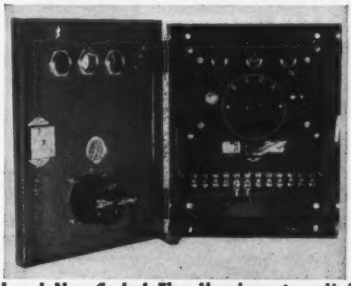
This Fire Headquarters Unit is designed to be used primarily for the receipt of signals at a remote station when actuated by a local alarm unit in the protected premises. It is electrically supervised and will give a trouble signal in case of open and ground and will also receive an alarm under these conditions. This panel is made for 12 or 24 volt D.C. operation.



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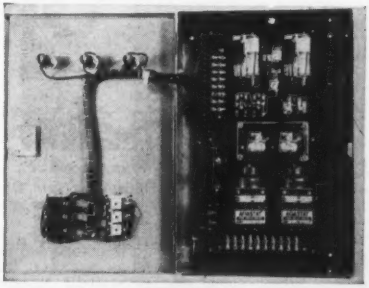
This single circuit panel is mounted in a red metal cabinet 18 x 12 x 6 inches, with switches and lights. This panel operates on the well known McCulloh principle. Signals are ordinarily received over a closed supervised circuit. With the McCulloh principle, a signal will be received over the circuit even though a single break or a single ground, or both, has occurred on the signaling circuit. This panel automatically adjusts the circuit for these fault conditions instead of the customary switches which are adjusted manually. A break or ground will be immediately indicated by a light and audible signal. The relays used in this panel are very sensitive and will receive signals from a considerable distance on No. 26 gauge wire and longer distances from heavier gauge wire. This panel operates on 24 or 48 volts of D.C. and requires a battery and rectifier for its operation.



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Manual fire alarm boxes, automatic sprinkler alarm transmitters, automatic fire alarm, watchman supervisory signals, etc. can be received and recorded on this panel.

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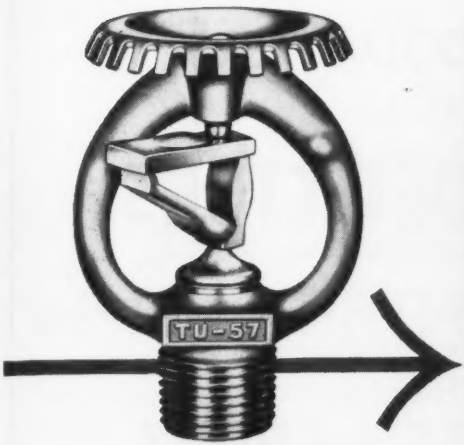

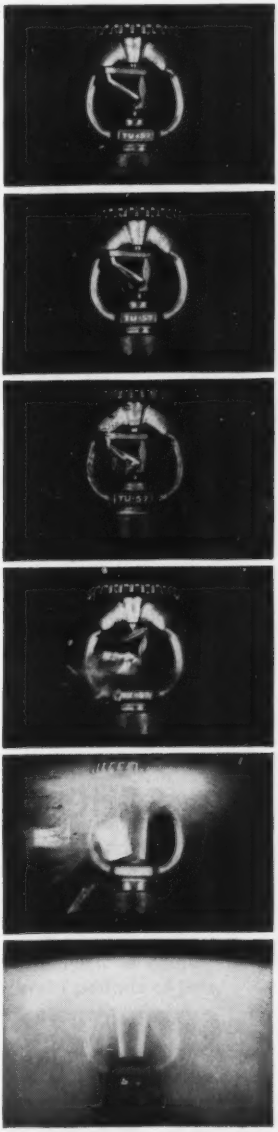

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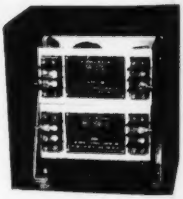

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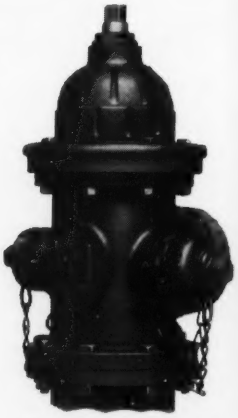
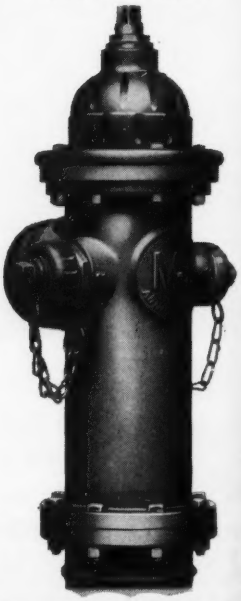


Above: Standard Model.
Below: Traffic Model.



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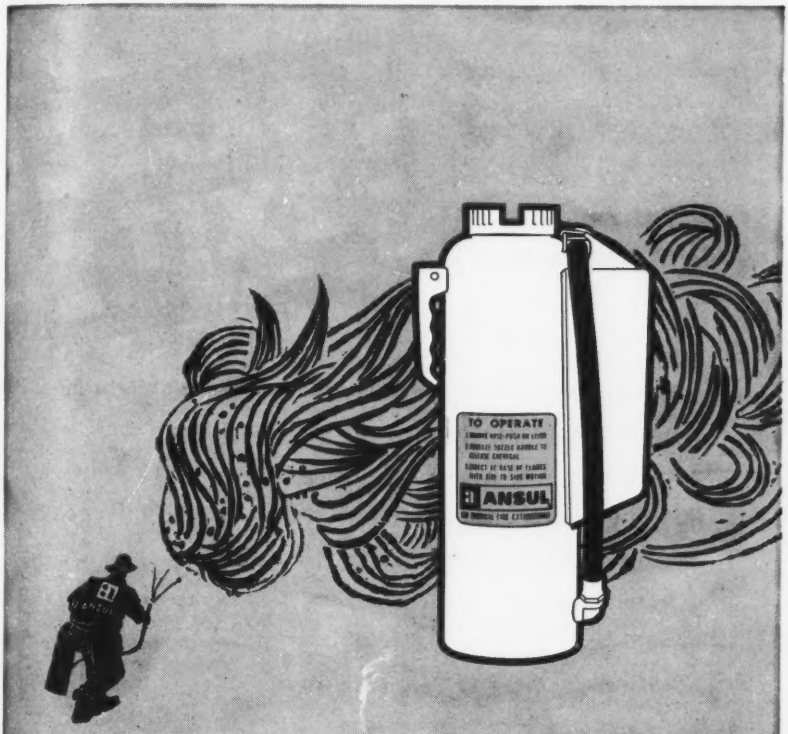

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by the Safety Check he uses

That "slide rule" on the installer's clipboard is a brand new service tool—the **Metalbestos Gas Vent Calculator.** With it the Metalbestos man can figure vent sizing for all types of heating jobs, quickly and accurately... and double-check the results to make certain his installations meet code requirements. It's based on the same established formula behind the Metalbestos Safety System Gas Vent Tables.

See your local Metalbestos representative or write Dept. 1-2

AVAILABLE ONLY FROM METALBESTOS • Gas Vent Calculator • Reader's Digest Reprints • Color Slide Film "Heat in Harness" • Venting Schools • Vent Installation Handbook • Gas Vent Service Bulletins • Safety System Seals • Sales & Technical Literature • Ad & Article Reprints • Direct Mail Materials.

METALBESTOS DIVISION
WILLIAM WALLACE COMPANY
BELMONT, CALIFORNIA

MANUFACTURING PLANTS IN BELMONT, CALIFORNIA • LOGAN, OHIO

"Worthy of Your Confidence!"

Reliable Automatic Sprinkler Devices have been protecting life and property for more than 35 years. The practical design and rugged construction are universally approved and accepted by all Fire Insurance and Governmental Authorities. Reliable Automatic Sprinklers effect maximum reductions in fire insurance premiums.

Reliable's complete line provides a wide selection of Sprinkler Devices to meet any condition, including: Automatic and Open Sprinklers, Alarm Valves, Dry Pipe Valves, Accelerators, Electric Alarm Switches, Water Motors, and all Sprinkler System Accessories.

Experienced Reliable Licensees are located throughout the United States, Canada, and foreign countries. They are expertly qualified to design and install a Reliable Sprinkler System for your specific needs.

THE RELIABLE AUTOMATIC SPRINKLER CO. INC.

"AKBAR"

THE FAMOUS

KINNEAR

Steel Rolling

FIRE DOOR

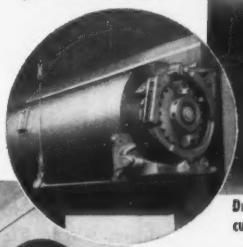
LABELED by Underwriters Laboratories, Inc.

Automatic positive-action Closure

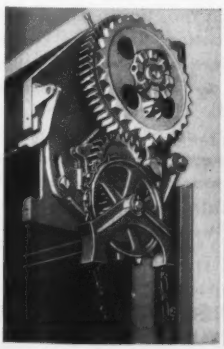
You get *positive, automatic* fire protection wherever openings are equipped with AKBAR Rolling Fire Doors (made *only* by Kinnear). The instant fire causes *automatic* release, they are *pushed* downward by a strong spring. Their closing speed is *controlled*, for safety. And they're operable *after* automatic release, for emergency exits.

Akbar Fire Door just after confining a devastating fire to room on other side of fire wall. Note fire extinguisher still on wall.

Drop-hood over main hood on curtain coil.



Right and below right: Manual Akbar operating mechanism. Below left: Mechanism of chain hoist "Akbar" Fire Door.



When closed, AKBAR Rolling Fire Doors block drafts, repel flames, keep fire from spreading. Kinnear Rolling Fire Doors can also be equipped for daily service, with motor or manual operation. (Use non-labeled Kinnear Rolling Doors where fire protection is not required.) Write for full details!

The KINNEAR Manufacturing Co.

Factories:

2250-70 Fields Ave., Columbus 16, Ohio

1742 Yosemite Ave., San Francisco 24, Calif.

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KINNEAR

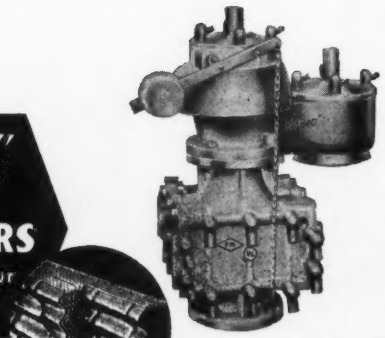
ROLLING DOORS

Saving Ways in Doorways

LOW COST
FIRE & EXPLOSION PROTECTION

for FLAMMABLE LIQUID STORAGE

WITH "Varec"
FLAME ARRESTERS
in combination with your
VENT VALVES



Flame Arrester Unit
listed by
UNDERWRITERS' LABORATORIES
Approved by Associated Factory Mutuals
Laboratories and other governing agencies.

Fig. No. 5800A
Conservation Vent Unit consisting of VAREC Vent VALVE in combination with VAREC FLAME ARRESTER

You can rely on VAREC CONSERVATION VENT UNITS to provide full fire protection on your liquid storage at low cost. Protection against entry of flame through the venting device is certain when Varec Flame Arresters are used. Protection against excessive pressure or vacuum is assured by the VAREC VENT VALVE. The combination unit gives you complete security against major hazards of flammable liquid storage. Average installation costs 1/10th of 1% of your investment in tank and products. Secure full details from your VAREC Representative or write factory.

NF-3

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

Cable Address: VAREC COMPTON USA
(All Codes)

code signaling

TRANSMITTER

is key to better plant

PROTECTION

Automatic coded signal transmitters are the nerve ends of Autocall Property Protection Systems. Working in conjunction with any type of sensing device, they transmit individual, distinctive signals to the Control Center where the Autocall-Howe Print Recorder indicates the signal in a printed message giving cause and location of the signal and the time of its origin.

Signals are positive, non-interfering and successive. If two or more transmitters are actuated at the same time, each operates in its proper turn.

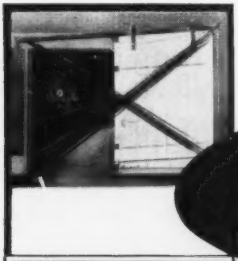
No signal can be lost or confused.

The benefits: Better supervision, better protection... and at greatly reduced costs. Your Autocall Sales Engineer can help you plan a new system or upgrade your present protection. There is no obligation for this service. Write, wire or phone, now.

Autocall®

PROPERTY PROTECTION SINCE 1912

THE AUTOCALL COMPANY • SHELBY, OHIO • SALES OFFICES IN PRINCIPAL CITIES



Old Type, Heavy, Cumbersome Fire Doors, Now Out-Moded by

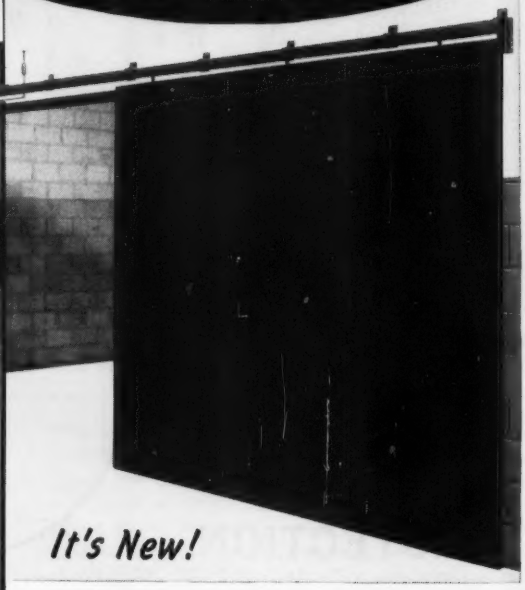
D-H PyroDor®

SLIDING FIRE DOOR

New Flush Design - New Forward Look

Class "A" Rating
3 Hour Fire Test

Temp. Rise 30 Min.
250° F. Max.



NEW!
PyroMatic

UL LABELLED AUTOMATIC DOOR CLOSER

It's New!

REQUEST CATALOG

DHSL-60 or Consult Sweet's Catalog Files

Unique design and flush styling is now available with the new D & H Sliding PyroDor for protection of wall openings formerly shackled to a 60 year old standard door type. Now, architects and engineers can specify D & H Sliding PyroDors and have the same solid structural mineral core construction as the D & H swinging PyroDors. Modern flush design, concealed hardware and the New UL Pyromatic door closer gives the Sliding PyroDor its attractiveness – *its forward look.*

Distributors Located in Principal Cities. Consult the Yellow Pages of your Phone Book or Write Direct.

THE MOST COMPLETE LINE OF FLUSH DOORS STEEL • ALUMINUM VINYL-ON-STEEL • WOOD

DUSING and HUNT, Inc.

Over 50 Years Manufacturing Fireproof Doors and Metal Trim

67 LAKE STREET **LE ROY, N. Y.**

Flintkote • Van-Packer Model HT Smokestack is UL-listed . . . ideal for incinerators & boilers

Wherever you see a Flintkote • Van-Packer Model HT Smokestack specified for incinerators, boilers or furnaces, you can be sure it will provide safe, reliable service. It is listed under the Factory Inspection and Label Service Program of Underwriters' Laboratories, Inc.

Van-Packer Smokestacks are erected from factory-built, insulating refractory sections. Each 3-foot section is encased in a corrosion-resistant metal outer jacket. Joints are sealed with acid-proof cement and secured with corrosion-resistant draw-up type joint bands assuring utmost strength and safety.

Model HT Smokestacks safely handle industrial incinerator flue gas temperatures up to 1800°F and up to 2000°F for occasional brief periods of forced firing. They won't corrode and average three times greater life than steel stacks. Insulating qualities of refractory wall prevent heat loss, give draft equal to brick and greater than steel.

Write for data file giving full information on Flintkote • Van-Packer Smokestacks.

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Division of The Flintkote Company
Manufacturer of Diversified Products for Home and Industry

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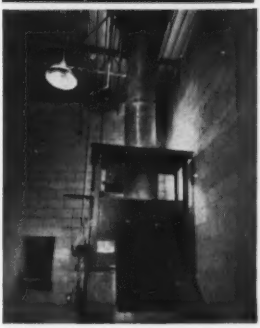
In the West: *Pioneer Division, The Flintkote Company Box 2218, Terminal Annex, Los Angeles, Calif.*

In Toronto, Ontario: *The Flintkote Company of Canada, Ltd.*



Smart Safety Directors specify SAFETEX fabrics when they order safety clothing. They know by test and experience that no other fabric performs like SAFETEX. Another Wamsutta/Pacific scientific triumph in the field of industrial fabrics, SAFETEX gives your workers maximum clothing-safety against fire and burns...regardless of repeated launderings. SAFETEX is Wamsutta/Pacific quality —and your experience with other Wamsutta/Pacific industrial fabrics tells you this means *top* quality. Protect your workers' lives... and your plant reputation by specifying SAFETEX fabrics from your safety-clothing sources. Or call Wamsutta/Pacific Industrial Fabrics Division for full information. Truly—you can't afford to pass up SAFETEX fabrics; the cost may be a life!

WAMSUTTA/PACIFIC INDUSTRIAL FABRICS, 1430 Broadway, New York 18, N.Y.

FIRE DOORS OR SUITS...

it pays to look for the label!

Would you buy a suit without looking at the label? Of course you wouldn't. As everyone knows, the label on your suit is an indication of the manufacturer's reputation for quality and workmanship.

For the fire protection specialist, the Underwriters' Laboratory label on a fire door guarantees quality and workmanship *plus proven performance*. It means the manufacturer's door has been fire tested and labeled by U/L, and that future labeled doors produced by him will be examined in his plant to guarantee identical quality standards with those fire tested.

When the U/L inspector visits the door manufacturing plant, he'll make certain that labeled doors are mortised and reinforced for a listed lock—they should not be labeled if they aren't. He'll be certain that the glass size and depth of setting in door lights meet U/L requirements for fire resistance. Louvers in fire doors are never approved by a U/L inspector—no louvered fire door has been successfully U/L tested to date. If a door has a fire-exit device, he'll require that it has a supplementary label, to assure the owner that it was factory installed and successfully tested for life safety as well as fire resistance.

One of the practices he won't approve is defining a door as "labeled construction"—he knows that the term "labeled construction" actually means *not labeled*, probably because some feature of the door has not or could not be successfully tested.

So when you buy doors, be sure and look at the label. And when looking at labeled fire doors, you'll want to talk to Overly—the company with the largest selection of U/L tested and labeled fire doors available today. Send for the 1960 Overly Fire Doorater for complete data.

Overly
MANUFACTURING COMPANY
Greensburg, Pa. St. Louis 19, Missouri Los Angeles 39, California

NOW... Kuhns ductile iron fittings

For Sprinkler Systems

Kuhns ductile iron pipe fittings—the newest development in piping—provide an extra margin of operating safety for sprinklers, high pressure lines and other vital piping systems. High structural strength and resistance to thermal shock help these fittings prevent leakage caused by vibration, temperature changes or misalignment.

"K" Pipe Lock Couplings

Listed for 800 psi by Underwriters' Laboratories, Inc., these couplings have a safety factor of five times the UL listing for 2½" through 6" and four times UL listing for 8". Sizes: 2½" through 8". Look for the "800 D" on each.

"K" Flanges and Flanged Fittings

Pressure rating, 500 psi by Underwriters' Laboratories, Inc. for elbows, base elbows, 45° elbows, side outlet elbows, tees, side outlet tees, and reducers in straight and reducing sizes. Flat faced flanges standard. Extra heavy flange dimensions and raised faces available. Look for the "DI 500" on each.

Complete range of sizes through 12".

"K" Screwed Fittings *

Pressure ratings listed by Underwriters' Laboratories, Inc.

STEAM AND OIL AT 550°F

¼" to 3".....300 lbs.

LIQUID AND GAS AT 150°F

¼" to 1".....2000 lbs.

1¼" to 2".....1500 lbs.

2½" to 3".....1000 lbs.

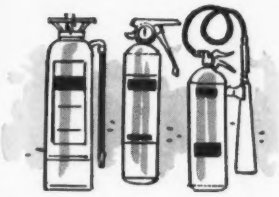
*Ductile iron fittings are available in any size in Kuhns complete cast iron line, ¼" through 12".

Note: These fittings are excellent for liquefied petroleum gas systems. Look for the "DI 300" on each.

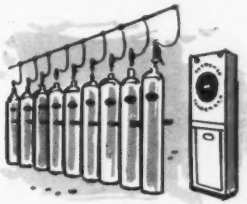
Send for our catalog or contact your wholesaler.

THE KUHNS BROTHERS CO.

1800 McCALL STREET, DAYTON, OHIO



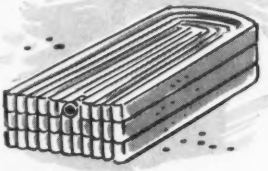
Fyr-Fyter, Pyrene-C-O-Two Buffalo fire extinguishers



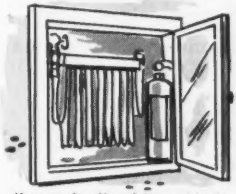
C-O-Two carbon dioxide, dry chemical, foam systems

Globe sprinkler systems

Fyr-Fyter fire alarm systems



Municipal, industrial fire hose



Hose and extinguisher cabinets

Wooster brass fire equipment

Fire department supplies

complete fire protection from Fyr-Fyter

Complete fire protection requires many different kinds of equipment. Fyr-Fyter can supply all the dependable, high-quality products and services you'll need!

You also surely need the deep knowledge and experience acquired by Fyr-Fyter representatives in industrial, commercial, institutional, municipal and household fields. These men are uniquely qualified to survey, analyze and recommend the proper equipment to guard every fire risk.

To contact the representative nearest you, look in the yellow pages under "Fire Protection Equipment" or write to: The Fyr-Fyter Company, 221 Crane Street, Dayton 1, Ohio.

Fyr-Fyter

Representatives and Distributors in all principal cities.

do your FOAM LIQUIDS measure up to these standards?

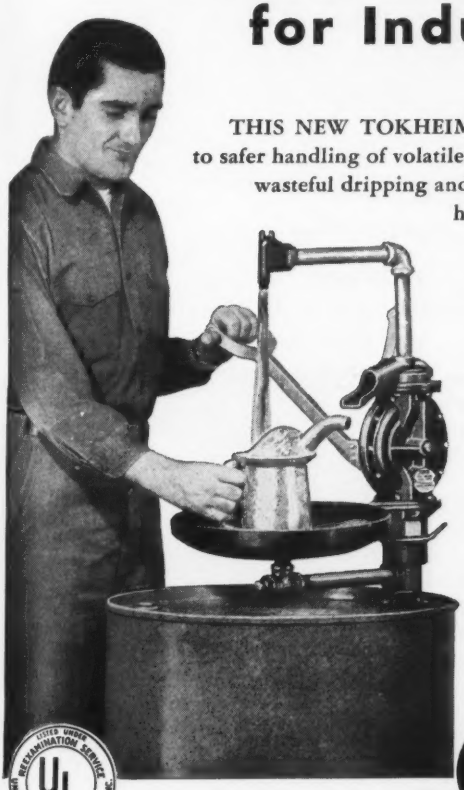
1. Is your foam liquid listed under the Underwriters' Laboratories' Reexamination Service? ☐ Yes ☐ No
2. Is every batch of foam liquid fire tested at the factory before it is shipped to you? ☐ Yes ☐ No
3. Does your foam liquid have a good record of stability over years of storage, and is it free from sediment that might foul the action of your equipment? ☐ Yes ☐ No
4. Is your foam liquid supplier able to make fast emergency shipments at any time of day or night? ☐ Yes ☐ No
5. Does your foam liquid supplier maintain active foam liquid research, development, and technical service programs? ☐ Yes ☐ No
6. If your foam liquid may be used below 10°F, is it a true "Cold Foam" liquid that will proportion properly at temperatures down to —20°F? ☐ Yes ☐ No

If you can answer YES to all six questions, you're already using National Aer-O-Foam Liquids. If not, you need them! For full information, write for Booklet B

NATIONAL FOAM SYSTEM Inc.
West Chester, Pa.

SAFER

liquid handling for Industry



THIS NEW TOKHEIM HAND PUMP contributes to safer handling of volatile liquids wherever used. Stops wasteful dripping and slippery floors. Reduces fire hazard and accidents common to other methods of liquid transfer. Approved for handling petroleum liquids —ideal for many others. Available in 22 different *models for 'most any use*— from pipe lines to drums, or underground tanks, with hose or spout outlets. Order from your dealer, your oil company, or your Tokheim representative.

Write factory for literature.

QUALITY TOKHEIM HIGH VACUUM HAND PUMPS

General Products Division
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DESIGNERS AND BUILDERS OF SUPERIOR EQUIPMENT SINCE 1901
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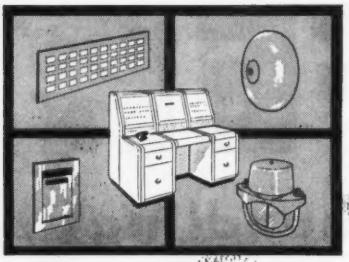
Subsidiaries: Tokheim International, A. G., Lucerne, Switzerland; GenPro Inc., Shelbyville, Indiana; Tokheim of Canada, Ltd., Toronto, Ontario

using National Aer-O-Foam Liquids. If not, you need them!
For full information, write for Booklet B
West Chester, Pa.



NOTIFIER'S

FIRE PROTECTION AND SECURITY SYSTEM

- - - protects another of the nation's outstanding buildings.

Notifier is entrusted with the responsibility of protecting the National Bank of Detroit's new Main office in the heart of Detroit's financial district.

NOTIFIER WAS CHOSEN BECAUSE OF:

- **Flexibility for meeting complex requirements**
- **Advanced electrical design**
- **Reliable performance over long life**
- **Plug-in components to permit easy maintenance**

National Bank of Detroit
Architects-Engineers: Albert Kahn Associated Architects and Engineers, Inc., Detroit

Do you have special plant protection problems? Let us help you solve them with Notifier's modern electronic equipment. A Notifier Sales Engineer will give you complete data on basic systems.

NOTIFIER CORPORATION
3700 North 56th St. Lincoln, Nebraska

NOTIFIER FIRE ALARM

AUTOMATIC

ROLLING-STEEL FIRE DOORS

PREFERRED FOR USABILITY . . . SPECIFIED FOR PROTECTION

ABOVE: A Mahon Rolling Steel Fire Door Serves a dual purpose—an internal dividing wall and an automatic fire barrier. BELOW: Window shutters too, are Mahon—supplied in sizes to your need for full fire protection.

Automatic Fire Doors and Shutters from Mahon have been carefully engineered to offer you many advantages of safety and function. They are operated manually or mechanically in everyday use—automatically closing if fire breaks out. This quick action cuts off drafts, confines the blaze and reduces losses. No other type of fire door provides all of these important features: Underwriters' Label; vertical roll-up action, minimum space demands; all-metal construction; Bonderite-protected plus rust-inhibiting synthetic baked enamel; and quality built for long life. You will find a Mahon Automatic Fire Door or Shutter to suit your use . . . your property . . . your protection.

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THE R.C. MAHON COMPANY
Detroit 34, Michigan

MANUFACTURING PLANTS—Detroit, Mich. and Los Angeles, Calif. BRANCH OFFICES in New York, Chicago, Los Angeles and San Francisco. SALES REPRESENTATIVES in all other principal cities.

MAHON

OTHER MAHON BUILDING PRODUCTS INCLUDE UNDERWRITERS' RATED METALCLAD FIRE DOORS

Nation Wide
Central Station Protection Services

Sprinkler Valve Alarm — Complete Sprinkler Supervisory — Manual Fire Alarm — Automatic Fire Alarm — Temperature Alarm — Oil Burner Supervision — Burglar Alarm — Hold-Up Alarm — Vault & Safe Protection

Available from these members of

Central Station Electrical Protection Association

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BOSTON, MASS.	**CALL'S CENTRAL STATION ALARMS** 69 Washington Avenue, Chelsea
CHICAGO, ILLINOIS	**CENTRAL WATCH SERVICE** 214 West Ohio Street
CLEVELAND, OHIO	**MORSE SIGNAL DEVICES** 6707 Carnegie Avenue
DALLAS, TEXAS	**SMITH DETECTIVE AGENCY & NIGHTWATCH SERVICE, INC.** 610 N. Akard Street
DAYTON, OHIO	**DAYTON ELECTRONICS ALARM & SIGNAL CO.** 301 West Monument Avenue
DENVER, COLORADO	**DENVER BURGLAR ALARM COMPANY, INC.** 422-21st Street
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LOS ANGELES, CALIF.	**MORSE SIGNAL DEVICES OF CALIFORNIA** 211 So. LaBrea Avenue
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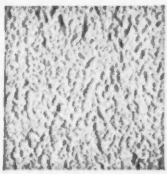
INCOMBUSTIBLE CEILINGS
—*and they're ALL* by "CELOTEX"

Here are some examples of "Ceilings by Celotex" that meet building code requirements for incombustibility.

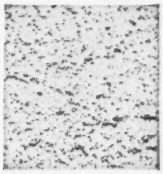
ALL ARE U.L. LISTED

FISSURED MINERAL FIBER TILE

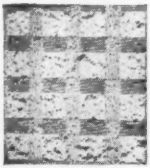
STRIATONE*



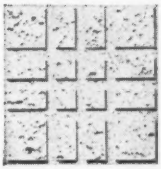
TEXTURE-TONE*



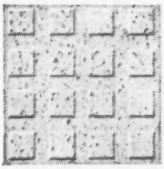
CELOTONE®



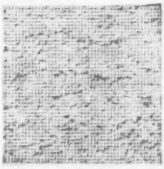
"DESIGN" CELOTONE® Plaid



"DESIGN" CELOTONE® Monarch

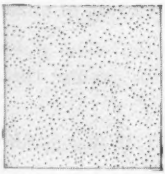


"DESIGN" CELOTONE® Empress



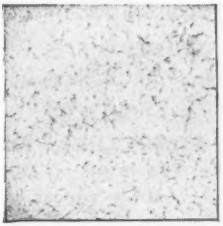
"DESIGN" CELOTONE® Modulo

PERFORATED MINERAL FIBER TILE



SERENE
Also available in Random Perforated Patterns and Standard Perforated Pattern.

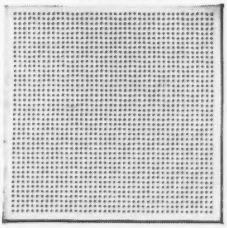
GLASS FIBER PANELS



SUPRACOUSTIC®

*TRADE MARK

GYPSUM BOARD ASSEMBLY



CAVITY TILE†

†U. S. PAT. NO. 2,838,806

If it's "by CELOTEX" you get QUALITY . . . *plus!*

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GIVES YOU MORE — FOUR WAYS

UPRIGHT SPRAY SPRINKLER

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APPROVED BY
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SIDEWALL SPRINKLER

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UNDERWRITERS' LABORATORIES, Inc.

SMALL ORIFICE SPRINKLER
(With Identifying Pintle)

1 **SUPERIOR PROTECTION** . . . due to more efficient water distribution. Proven by tests under actual fire conditions for all classes of hazards.

2 **MORE EFFECTIVE USE OF LESS WATER** . . . because wider distribution and break-up of the water discharged provides greater cooling and extinguishment.

3 **CEILING PROTECTION BY COOLING — NOT WETTING** . . . All the water goes onto the fire. The break-up of water results in complete cooling and control of flammable vapors.

4 **MORE FIRE CONTROL WITH FEWER SPRINKLERS** . . . because ceiling temperatures are kept lower, fewer sprinklers open. Immediate water saturation of the fire area prevents the spread of fire. Hot gases become impotent in the cooled atmosphere.

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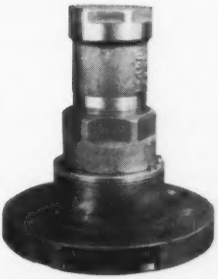
When pressure drops . . . the spring-tensioned S&J valve closes tight — quickly! Positively! In LPG tanks, pipe lines, and manifolds, the S&J Internal Safety Valve (Fig. 6129) is your most reliable safeguard. 5 sizes: 2", 3", 4", 6", 8". Get the facts: your inquiry will receive immediate attention.



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BERKELEY, CALIFORNIA
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AN ADVERTISEMENT

What variations from tested floor-ceiling assemblies are permissible?

Armstrong Acoustical Fire Guard—the first time-design-rated acoustical ceiling tile—will meet the nation's strictest building codes. And it will do it in a wide variety of floor-ceiling assemblies.

most popular constructions have been tested

Since the elements of a floor-ceiling assembly (such as the tile, the slab, the air space in the plenum, and the structural steel supporting the slab) can be varied and these variations can be combined in an infinite number of assemblies, it is virtually impossible to test and report every one. The more popular assemblies have been tested. Variations from tested assemblies which maintain or improve the fire-retardant rating have been accepted by local code officials, building inspectors, and rating agencies.

slab construction may vary

A thicker slab logically improves fire retardance of the assembly. Equivalent thicknesses of poured or precast lightweight concrete or gypsum may be substituted for structural grade concrete. The National Board of Fire Underwriters—sponsoring agency for U. L.—has listings in its fire-resistance rating booklet that state alternate fills of equivalent thickness are permissible in rated assemblies.

modification in structural steel

Acoustical Fire Guard forms a tight fire-retardant membrane which blocks passage of dangerous heat and flame. Structural steel, regardless of its size and shape, will not fail so long as it does not become overheated.

depth of plenum chamber

In the official U. L. test assemblies, the metal members supporting the tile were in direct contact with the structural member — the most critical construction possible. Suspension of the ceiling to create a deeper plenum would not impair the fire retardance of the assembly.

Before you specify your next ceiling, consider Armstrong Acoustical Fire Guard. It will help you give your client a safer building—often at a savings in cost. For more information, contact your Armstrong acoustical contractor or your nearest Armstrong district office. Or write to Armstrong Cork Co., 4210 Woodbridge St., Lancaster, Pa.

Fire prevention through Safety Engineering

FLASH FIRES ARE ENCOURAGED HERE!

Here, in Ætna Casualty's laboratory, flammable liquids used by industry are carefully tested to determine their flash points. By discovering hazardous properties under controlled conditions, many potential fires and explosions are prevented.

Both in the laboratory and in industrial plants, the knowledge and facilities of Safety Engineers continually guard against the possibility of accidents caused by solvents, cleaners and other flammable fluids. This is one of many valuable Safety Engineering services, and you may get *full* details from your local Ætna Casualty representative.

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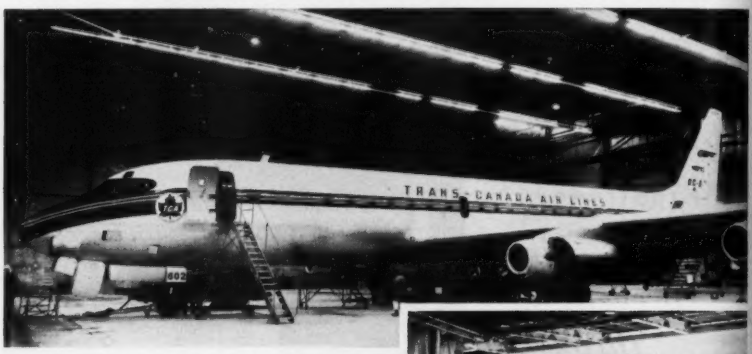
ALL FORMS OF CASUALTY, BONDING, FIRE AND MARINE PROTECTION

HIGH VALUES · MAXIMUM PROTECTION



"AUTOMATIC" SPRINKLER FOAM-WATER DELUGE SYSTEM

guards $26,000,000 hangars—helps maintain TCA record of customer service!

Trans-Canada Air Lines at its giant new Montreal Overhaul and Maintenance Base chose the "Automatic" Sprinkler Foam-Water Deluge System as maximum protection for the heart of its service facilities, two huge hangars—6 acres of floor space. Every square foot, every jig, fixture, part, every aircraft is guarded by over 3000 foam-water sprinklers ready to discharge fire-smothering foam.

Trans-Canada, in common with many other large transportation and industrial concerns, realizes the importance of protecting high values in equipment and customer relations with fast, reliable, positive protection.

INSTALLATION TEST shows fire-smothering blanket from Foam-Water System (Rate-of-Rise operated) installed by "Automatic" Sprinkler Co. of Canada, Ltd.

BEFORE YOU DECIDE

on protection for *your* high values against flammable liquid fires, see "Automatic" Sprinkler's new motion picture, "Automatic" Foam-Water Sprinkler Systems. Write today.

"Automatic" Sprinkler CORPORATION OF AMERICA

MANUFACTURERS AND INSTALLERS OF APPROVED FIRE PROTECTION EQUIPMENT

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His community showed the way . . .

Chief Thomas F. Gorman of Quincy, Massachusetts, knows that his city will continue to have positive, adequate, fire alarm protection facilities. Recently, Quincy became the first municipality to pass an ordinance requiring that all new residential and institutional construction have fire detection and alarm facilities within its confines.

Quincy's Semi-Automatic Gamewell Fire Alarm System protects all residential and high value areas through strategically located curb boxes. Master Boxes tie all hospitals, public schools, and a great many larger industrial buildings into the municipal system. Seconds after any box is pulled, Quincy's entire fire defenses, as well as police and waterworks, know its location.

Is *your* city this well protected? Gamewell will be happy to supply copies of the Quincy ordinance and conduct a fire survey to assist you in planning *better* fire protection. Write The Gamewell Company, 1280 Chestnut Street, Newton Upper Falls 64, Massachusetts. *A Subsidiary of E. W. Bliss Co.*

BLISS Gamewell®

FIRST . . . WHEN SECONDS COUNT

GRINNELL WATER SPRAY SYSTEM under test at the Marietta, Ohio plant of the Bakelite Union Carbide Plastic Company, a division of the Union Carbide Corporation. Water — when it is applied in time and distributed over the surfaces efficiently by a properly engineered system — is most effective in limiting tank fires and controlling their spread.

Keep tank fires from getting out of control with Grinnell Water Spray

Proper safeguards are uppermost in importance in protecting tanks which contain flammable gases and liquids in the event of fire. For example, tanks must be guarded against extreme heat exposure. Leaking gas, if it should develop, must be diluted to the point where it will not burn. And fire, if it should occur, must be localized and controlled or extinguished.

With a Grinnell Water Spray System, you get such protection.

Before heat raises tank temperatures dangerously, an enveloping spray of water provides instant cooling, reducing internal pressure which helps prevent rupture. In addition, air turbulence is created (even in still air) which, in conjunction with the water vapor from the spray, helps dilute the flammable vapors to control or extinguish the fire. Flammable products which cannot be safely extinguished can be safely burned off under the protecting water spray.

FREE REFERENCE MANUAL. For a comprehensive picture of all the most advanced methods of special hazard fire protection, request your free copy of "Special Hazard Fire Protection by Grinnell." Write Grinnell Company, Providence 1, R. I. Branches in principal cities.

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